

BELLCOMM, INC.

955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B71 03065

SUBJECT: The Effect of Recent Rendezvous Profile, SL-1 Insertion Conditions, and MSFN Changes on Tracking for Rendezvous - Case 610

DATE: March 30, 1971
FROM: W. L. Austin

ABSTRACT

Of the recent changes in the rendezvous profile, MSFN, and SL-1 insertion conditions, the most significant are the changes in the rendezvous profile and deleting the Guaymas station. Restricting NCL to always occur on the second apogee from SL-2 insertion, and the deletion of Guaymas means that Texas is the only station with a sufficiently long range and range rate pass to provide the required data for the ground computed NCL maneuver computation, regardless of M number.

(NASA-CR-117924) THE EFFECT OF RECENT
RENDEZVOUS PROFILE, SL-1 INSERTION
CONDITIONS, AND MSFN CHANGES ON TRACKING FOR
RENDEZVOUS (Bellcomm, Inc.) 76 p

N79-71977

Unclassified
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(ACCESSION NUMBER)		(THRU)	
FF No. 602(C)	76	B1	
(PAGES)		(CODE)	
CR-117924		30	
(NASA CR OR TMX OR AR NUMBER)		(CATEGORY)	
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MEMORANDUM FOR FILE

Introduction

A previous memorandum (Reference 1) presented the tracking coverage and orbital day/night cycles for the SL-2 short rendezvous opportunities ($M=5, 6, 7$) occurring on the first seven days after SL-1 launch. The purpose of this memorandum is to update the previous one by including the new rendezvous profile, the $M=8$ opportunities, the latest MSFN (S-Band) configuration (Antigua, Guaymas, and Grand Bahamas are deleted and Santiago is added), and the current launch date and time. These data are presented in Figures 2 through 19. Table 1 contains the names, abbreviations, and locations of the MSFN stations used.*

For each M number, the minimum, average, and maximum phase angle opportunities are shown in their order of occurrence. To illustrate the rendezvous profile, the SL-2 rendezvous maneuver points and the altitude at each apsidal crossing are shown in each figure. Also shown in each figure is the point where the slant range between SL-1/SL-2 is 300 nm. This point is labeled S/C NAV and is the point where nominal on-board navigation can begin. In each figure, time-zero is the instant of SL-2 launch.

The rendezvous trajectories, orbital day/night cycles and tracking coverage were generated in the same manner as Reference 1 with the following changes. The SL-1 launch time is 0930 EST on November 9, 1972, and the descending node at SL-1 insertion was changed to the present value of 153.25 degrees. The NCL maneuver always occurs 1-1/2 orbits after SL-2 insertion regardless of M number.

The coverage data presented in Figures 2 through 19 are generally applicable for any SL-1 date and time of launch. This is particularly true of the coverage from insertion

*The assumed location for Santiago is the same as the STADAN station presently located just outside Santiago.

through NSR as for any given M number and phase relationship (minimum, average, or maximum), the angle caught up from insertion through NSR is a constant. This can be seen by comparing Figures 2 and 11 which are M=5 minimum phase opportunities for different dates and times of SL-2 launch. However, the coverage from NSR through TPF will vary somewhat as the time in coelliptic orbit is a function of the sun's position in the orbit plane, which varies with date and time of SL-2 launch. Since the time in coelliptic orbit is constrained to not less than 30 and no more than 75 minutes, the reader can bracket the variation in NSR through TPF coverage by positioning the TPI and TPF events accordingly.

The M=5, 6, 7, and 8 rendezvous opportunities for the first seven days after SL-1 launch are shown in Figure 1. The circled numbers indicate the points in the launch window for which tracking data was generated. These numbers are identical to the figure numbers presenting the coverage data.

As there have been a number of changes in the SL-2 rendezvous profile, SL-1 insertion conditions, and number of MSFN stations since Reference 1 was published, their impact on the tracking coverage requires assessment. This is especially true of the critical period from insertion through NC2, as the ground is prime for NC1 and NC2 maneuver computations.

Coverage Analysis

Because of the volume, the tracking coverage data from Reference 1 will not be included here. However, the significant differences will be noted.

Nominally, on-board navigation can begin once the slant range between SL-1 and SL-2 is less than 300 nm. Reviewing Figures 2 through 19 shows there is adequate opportunity for on-board navigation prior to the NCC and subsequent maneuvers in all cases. This assumes 32 minutes is sufficient to perform navigation measurements and prepare for the maneuver.

There are two between-maneuvers MSFN coverage criteria (strict and relaxed) for ground computed maneuvers. The strict criterion requires coverage by two S-Band stations (at least three minutes each for range and range-rate measurements) which are sixty or more degrees apart in longitude to compute a good maneuver solution. A third station pass is required for up-linking. The last data used in the maneuver computation must be taken no later than ten minutes prior to the uplink station

pass and the uplink must occur no later than ten minutes prior to the maneuver. The relaxed criterion requires only one S-Band range and range rate pass coupled with a suitable uplink pass as defined above. This produces a degraded though acceptable state vector for maneuver computation.

Whether or not these MSFN coverage criteria are met is most important for the SL-2 insertion to NC1 and NC1 to NC2 coast periods as the ground is prime for NC1 and NC2 maneuver computations. Reviewing Figures 2 through 19 shows that the strict criteria is met for all NC1 to NC2 coast phases. However, for the insertion to NC1 coast phase, only the relaxed criterion is met in all cases.

For the previous rendezvous profile (Reference 1), the strict criterion was met or exceeded for all insertion to NC1 coast phases excluding the M=5 case. This degradation in coverage is due solely to the reduction in the number of orbits between insertion and NC1 for the M=6 and 7 rendezvous profiles and not the shift in SL-1 insertion descending node or the deletion of the Antigua and Grand Bahamas tracking stations.

The effect of deleting Guaymas is in the nature of a potential problem. For the present profile, the SL-2 and OWS state vector computations (for the ground computed NC1 maneuver) are to be based on range and range rate data obtained during the first Texas pass (Reference 2). This was also true for the previous M=5 rendezvous profile. However, with Guaymas in the MSFN, a backup was provided if Texas were unable to supply the data for the NC1 maneuver computation (Reference 1). Also, for the M=6 and 7 rendezvous neither Texas nor Guaymas was necessary to compute good NC1 and NC2 solutions.

The present profile coupled with the deletion of Guaymas means that Texas is the only station available to obtain range and range rate data for the NC1 maneuver computation in all cases. If Texas cannot supply the necessary data, the ground will not be able to compute a good NC1 solution in all cases.

From NC2 on, the MSFN acts as a backup to the on-board NCC, NSR, TPI, and TPF maneuver solutions. For M=5 and 6 (excluding the Day 1, M=5, maximum phase angle case), there is sufficient coverage to compute the NCC and NSR pair of burns and uplink the solutions. For M=7 and 8 and the

one M=5 case above, the NC2, NCC, and NSR maneuvers must be uplinked as a triplet because of insufficient tracking coverage for maneuver computations between NC2 and NSR. This was also necessary for the M=7 rendezvous opportunities in the previous profile (excluding the Day 7 minimum phase opportunity). M=8 was not included in the previous study. To the writer's knowledge, the quality of the maneuver computation for this procedure has not yet been evaluated by MSC.

It is interesting to note that the only impact of the addition of the Santiago station is to provide TPI coverage for the Day 2, M=8 opportunities and additional tracking between NSR and TPI for the Day 7, M=8 opportunities. This is the only time Santiago is even seen for the short rendezvous. It would probably play a more prominent role in the higher M numbers.

Summary

Of the recent changes in the SL-2 rendezvous profile, SL-1 insertion descending node, and number of MSFN stations, the most important factor from a ground tracking viewpoint is the change in the rendezvous profile. Limiting the NC1 maneuver to always occur 1-1/2 orbits after insertion means that MSFN coverage for the NC1 maneuver computation never exceeds the relaxed criteria.

Deleting the Antigua, Guaymas, and Grand Bahamas stations does not affect the overall quality of the coverage for rendezvous purposes. However, deleting Guaymas eliminates the only backup to Texas for all ground computed NC1 maneuvers. The only effect adding Santiago has on the tracking coverage is to provide TPI coverage for the Day 2, M=8 opportunities and additional coverage between NSR and TPI for the Day 7, M=8 opportunities.

W. L. Austin
W. L. Austin

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Attachments

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References

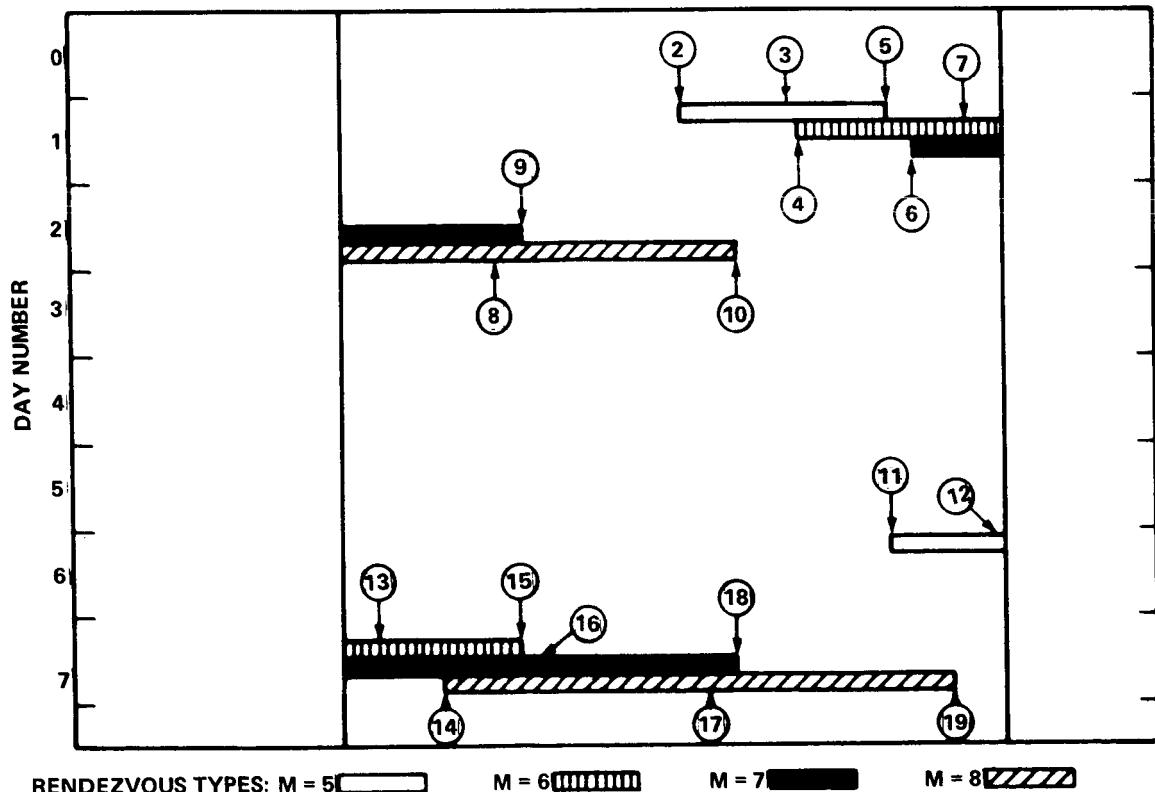
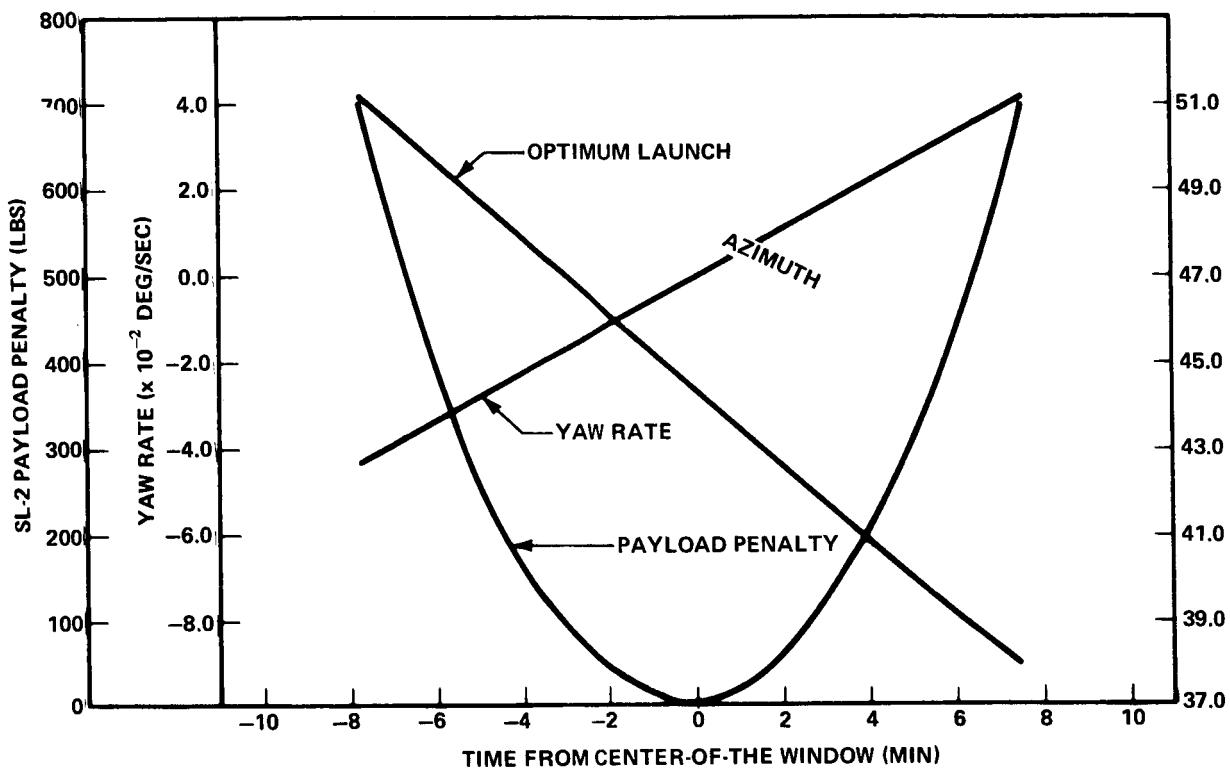
1. Tracking Coverage and Lighting for SL-2 Short Rendezvous, Case 610, Bellcomm Memorandum for File B70 09077, W. L. Austin, September 30, 1970.
2. Trip Report - Skylab Rendezvous Data Priority Meeting, MSC, C. O. Guffee, Bellcomm Memorandum for File B70 11005, November 3, 1970.

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Table 1

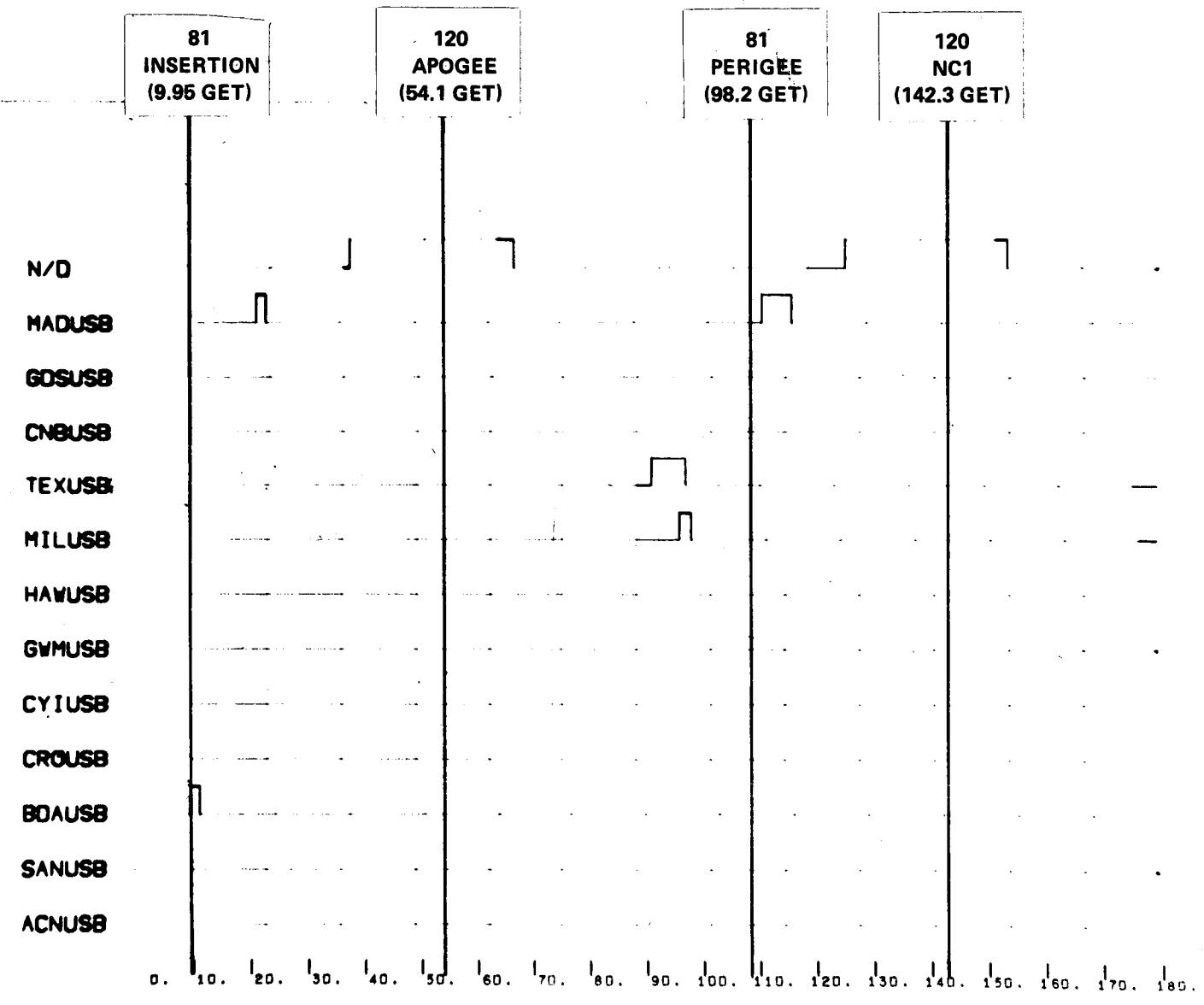
STATION NAMES AND ABBREVIATIONS

STATION NAME	LOCATION		ABBREVIATION
	Latitude	Longitude	
Ascension Island	7.955S	14.328N	ACN
Bermuda	32.351N	64.658W	BDA
Canary Island	27.765N	15.635W	CYI
Canberra	34.415S	148.977E	CNB
Carnarvon	24.908S	113.724E	CRO
Corpus Christi, Texas	27.654N	97.378W	TEX
Goldstone	35.342N	116.873W	GDS
Guam	13.309N	144.734E	GWM
Hawaii	22.125N	159.665W	HAW
Madrid	40.455N	4.167W	MAD
Merritt Island	28.508N	80.710W	MIL
Santiago	32.978S	70.669W	SAN



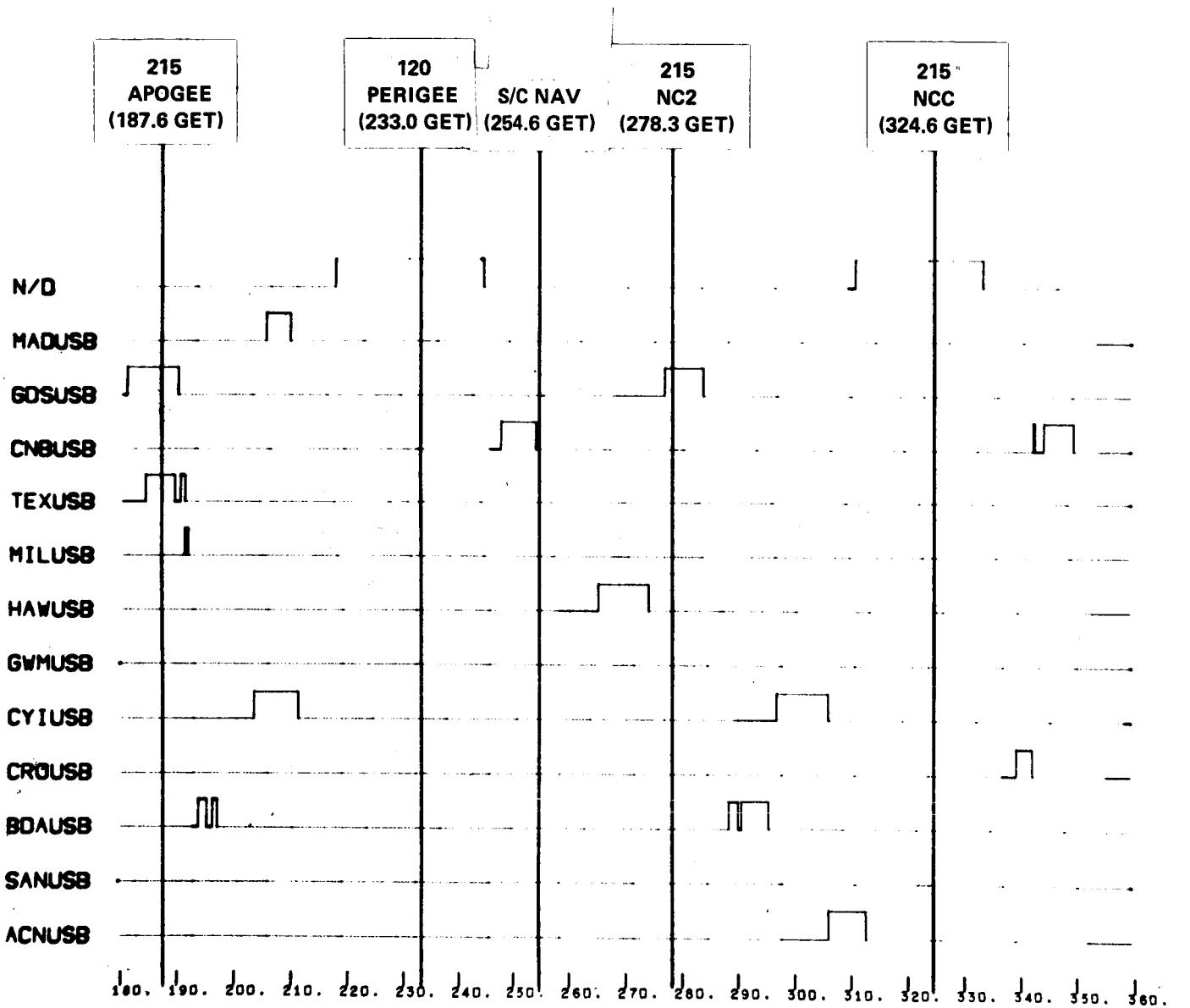
NOTE: CIRCLED NOS. CORRESPOND TO FIGURE NO.

FIGURE 1 - SL-2 SHORT RENDEZVOUS OPPORTUNITIES FOR THE FIRST SEVEN DAYS AFTER AN SL-1 LAUNCH AT 9:30 AM EST ON NOV. 9, 1972



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FIGURE 2 - SL-2 M = 5 DAY 1 MINIMUM PHASE OPPORTUNITY



GET - MIN

FIGURE 2 - SL-2 M = 5 DAY 1 MINIMUM PHASE OPPORTUNITY

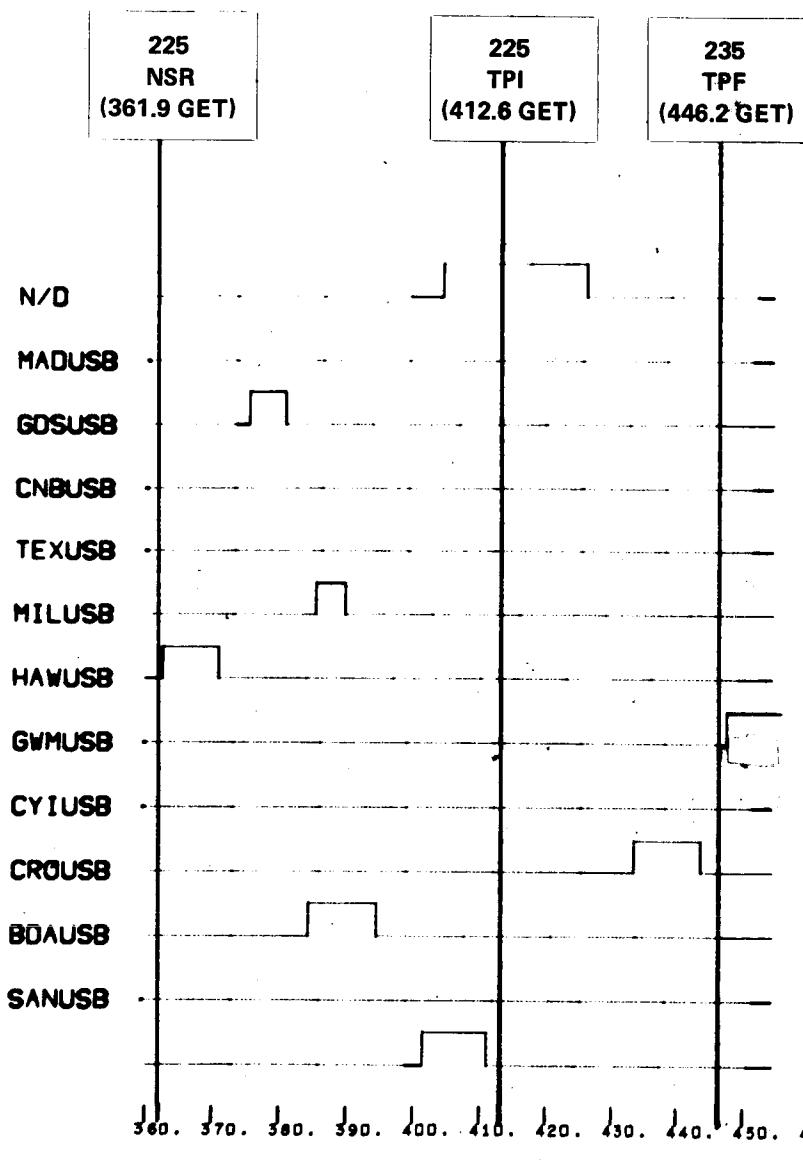
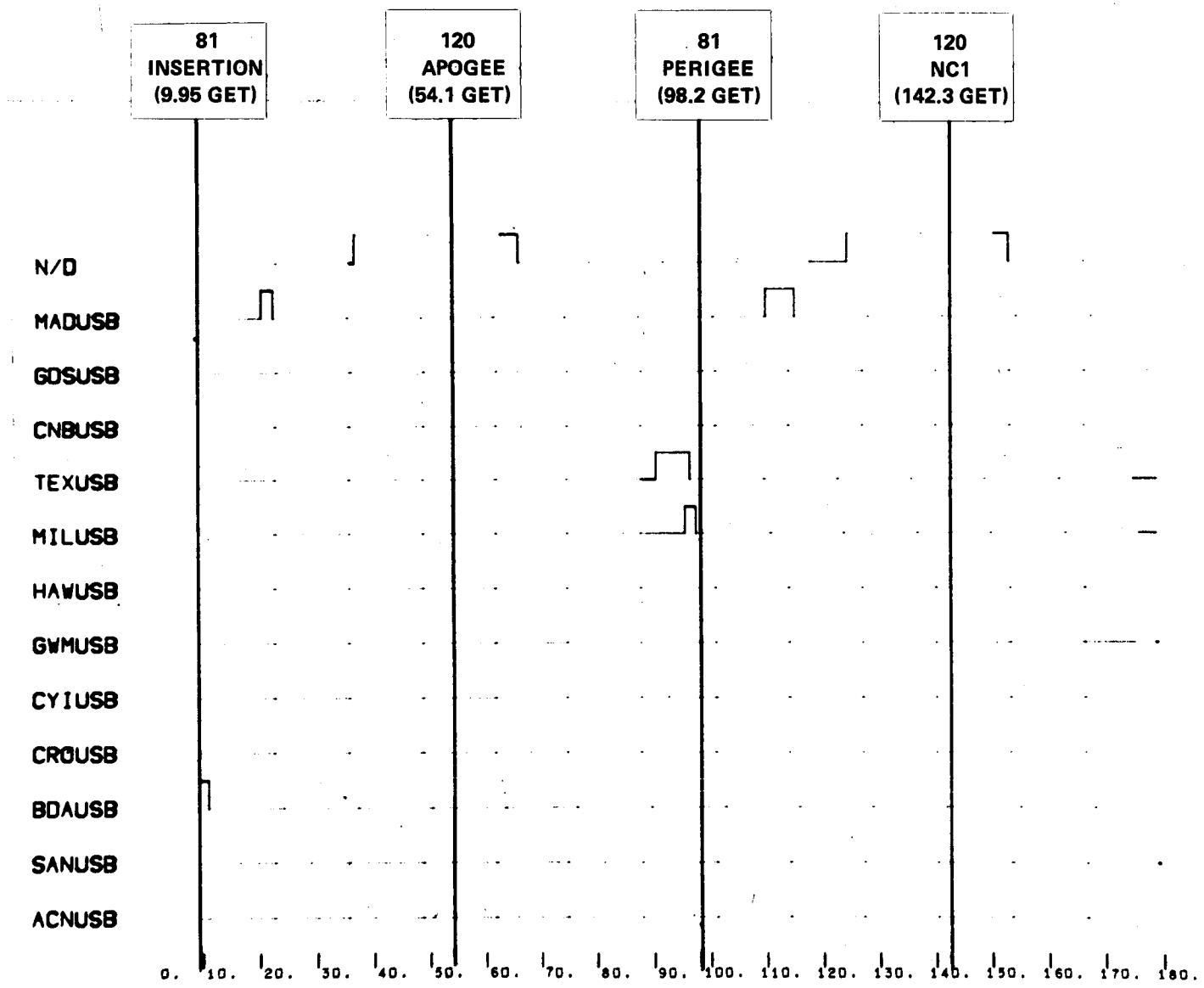


FIGURE 2 - SL-2 M = 5 DAY 1 MINIMUM PHASE OPPORTUNITY



GET - MIN

FIGURE 3 - SL-2 M = 5 DAY 1 AVERAGE PHASE OPPORTUNITY

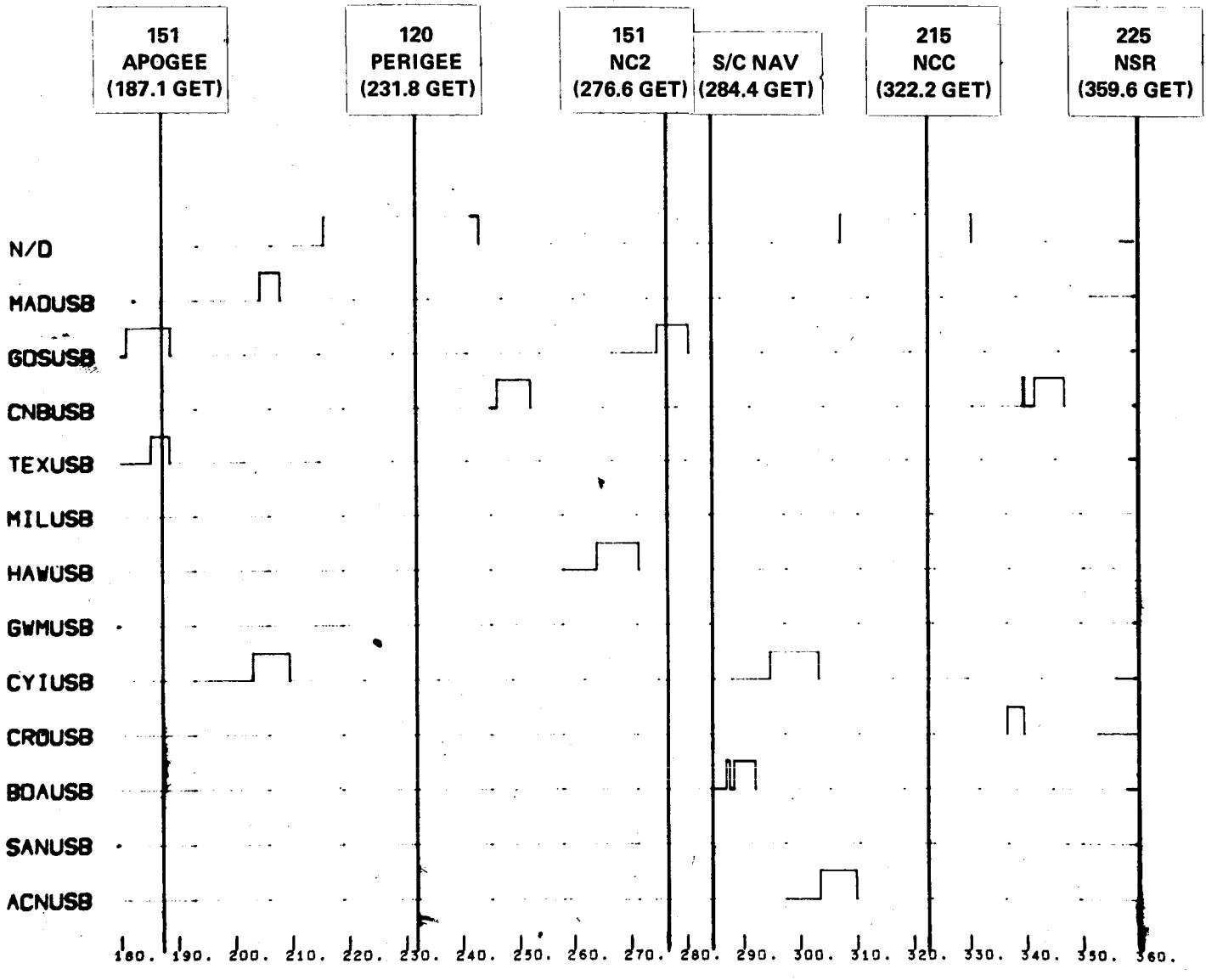


FIGURE 3 - SL-2 M = 5 DAY 1 AVERAGE PHASE OPPORTUNITY }

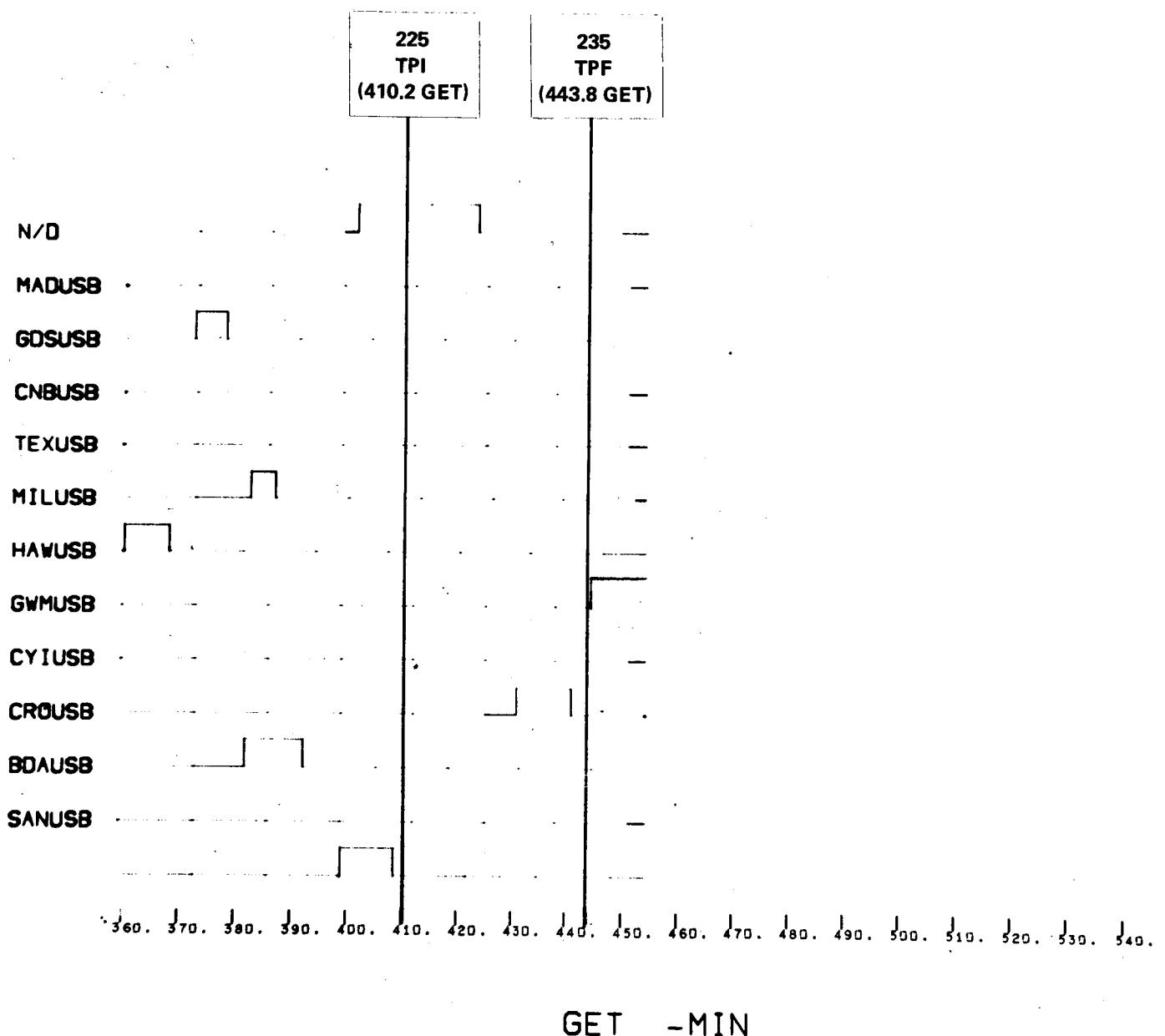


FIGURE 3 - SL-2 M = 5 DAY 1 AVERAGE PHASE OPPORTUNITY

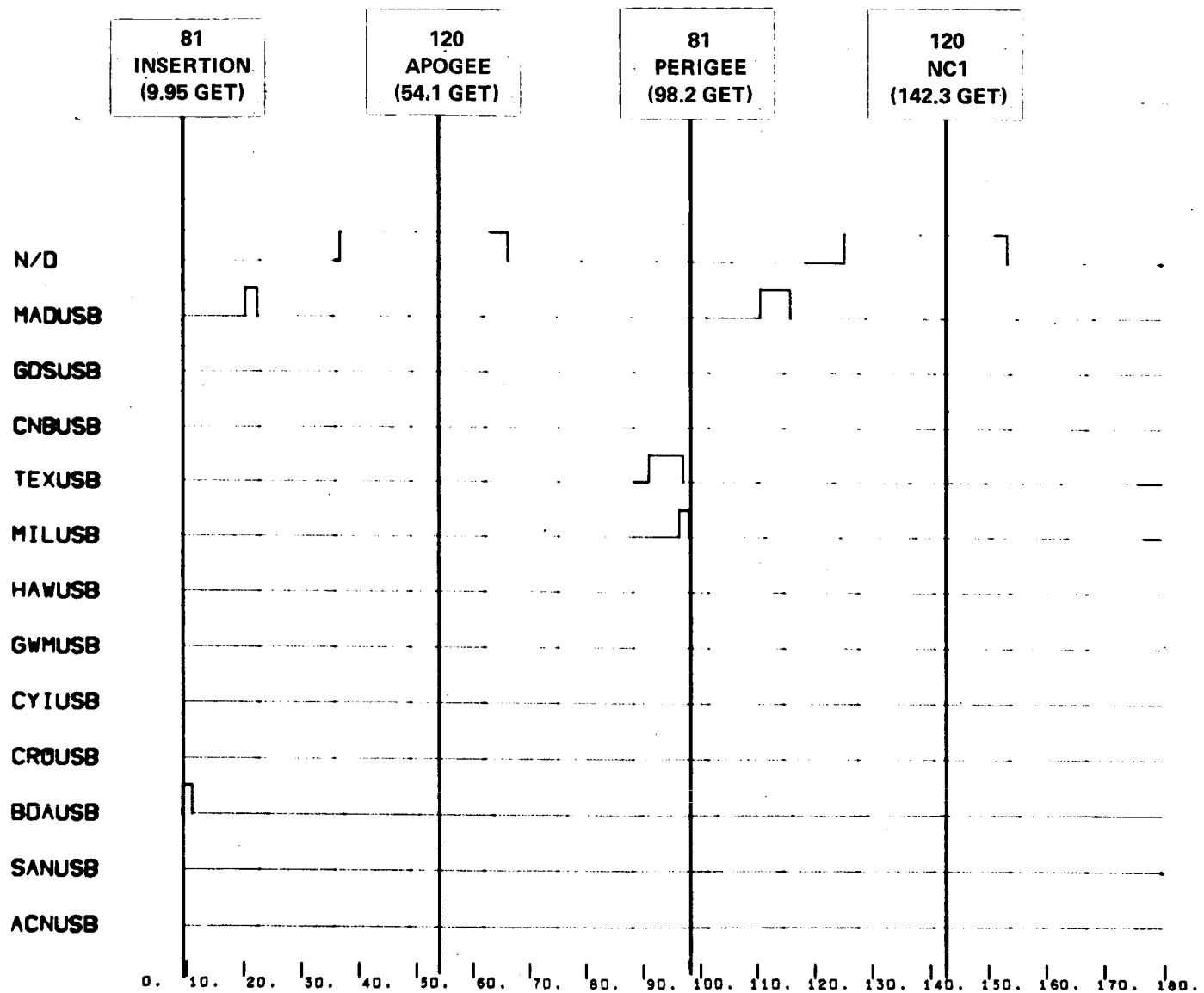
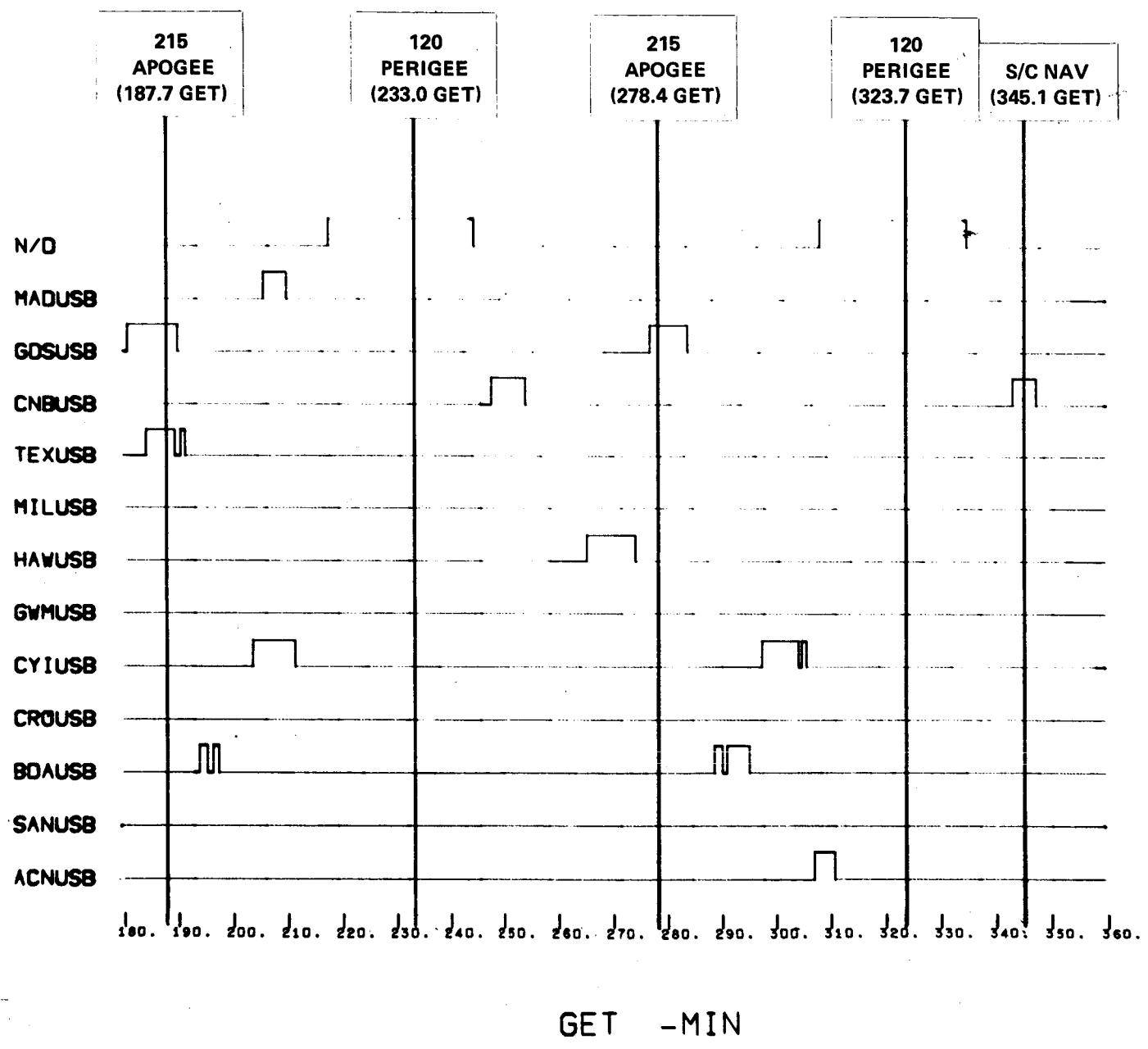
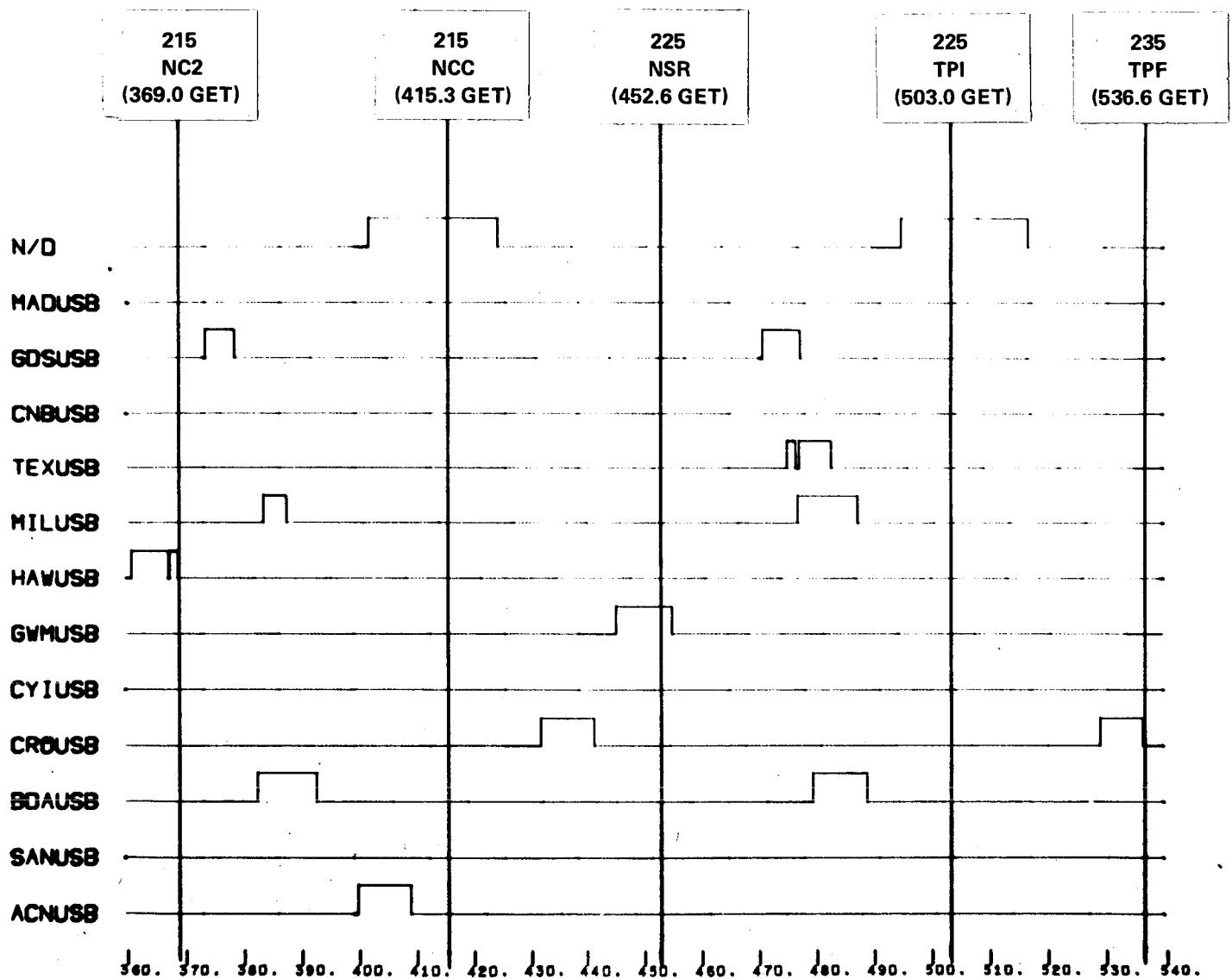


FIGURE 4 - SL-2 M = 6 DAY 1 MINIMUM PHASE OPPORTUNITY



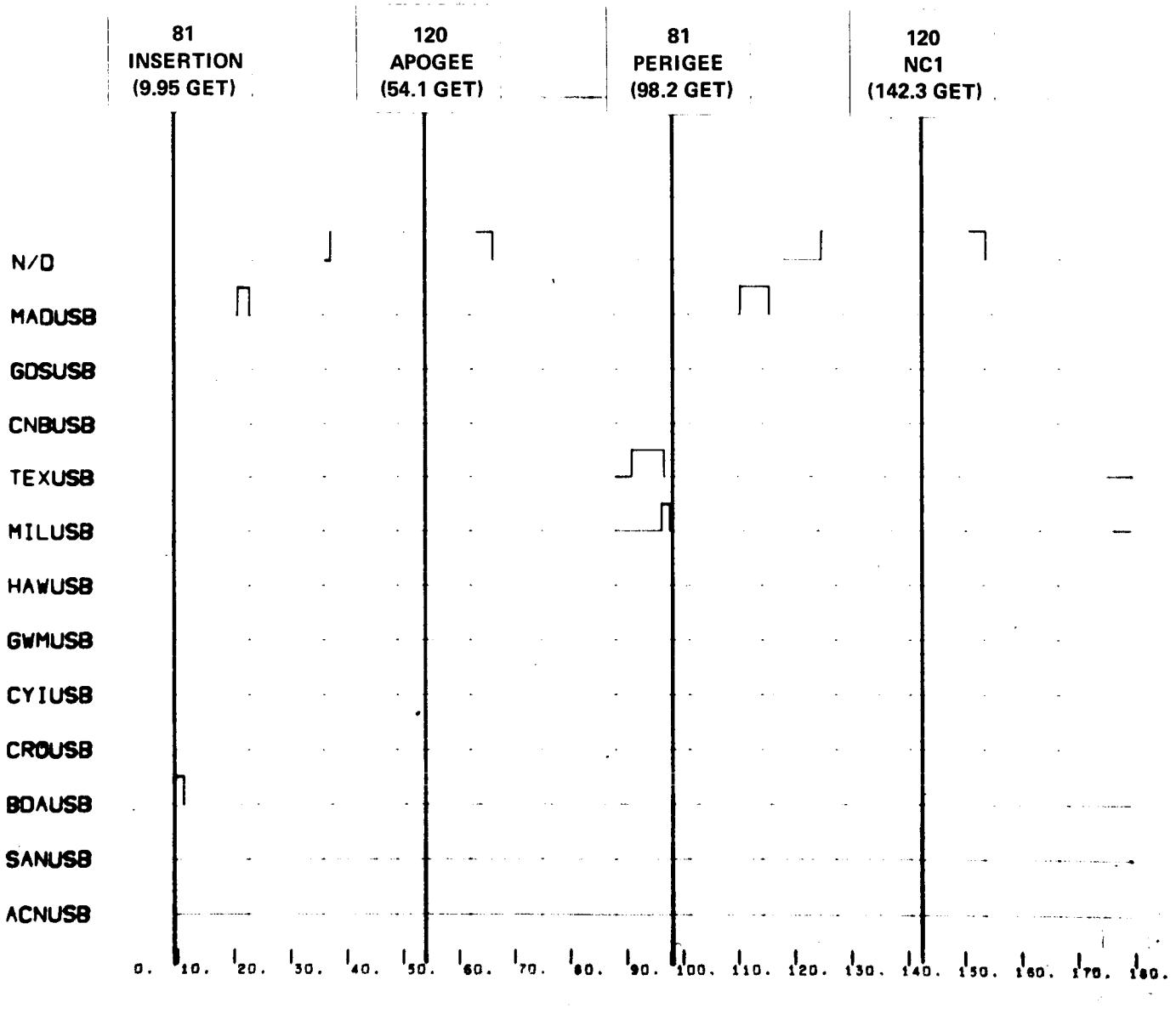
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FIGURE 4 - SL-2 M-6 DAY 1 MINIMUM PHASE OPPORTUNITY



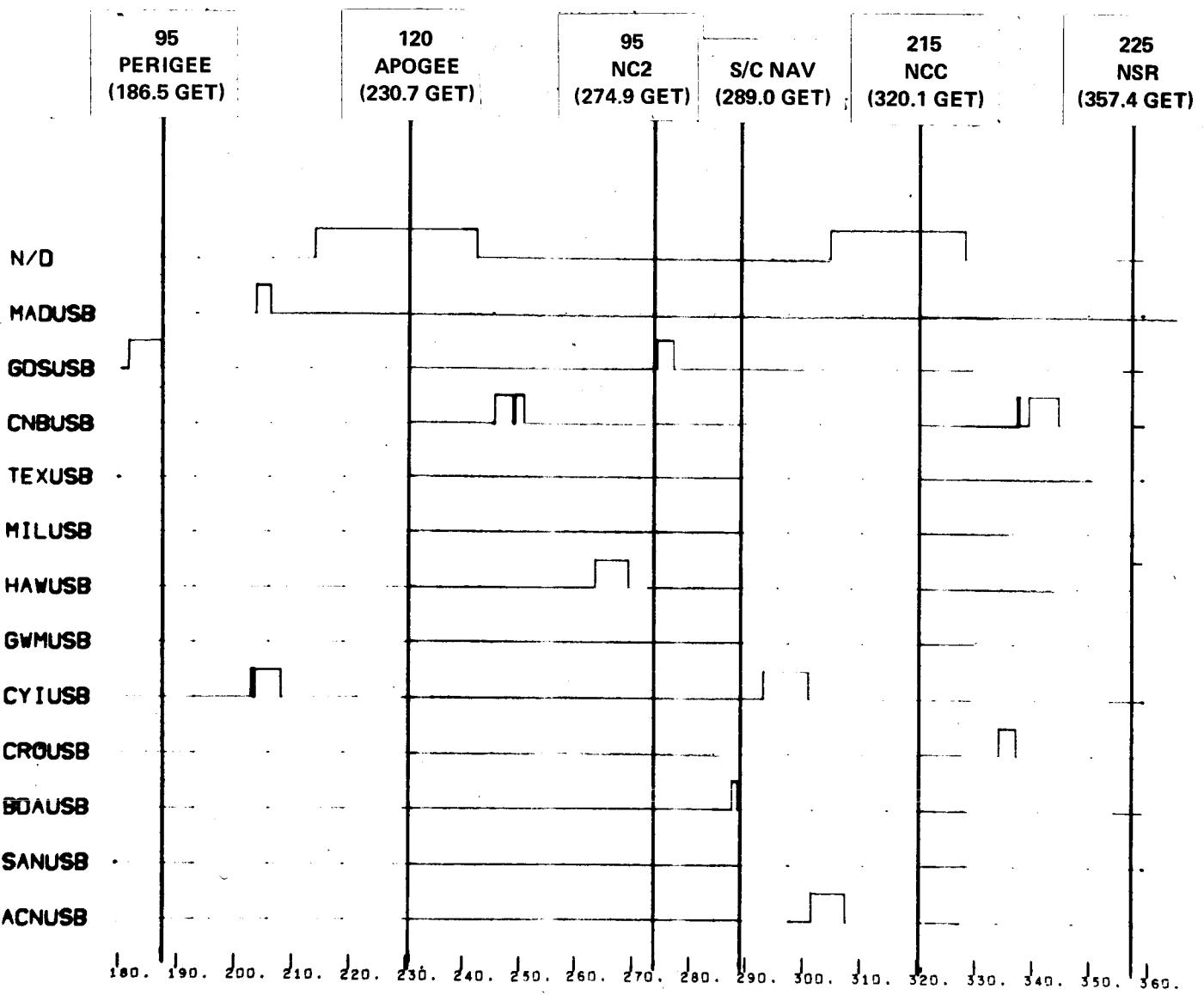
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FIGURE 4 - SL-2 M-6 DAY 1 MINIMUM PHASE OPPORTUNITY



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FIGURE 5 - SL-2 M = 5 DAY 1 MAXIMUM PHASE OPPORTUNITY



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FIGURE 5 - SL-2 M = 5 DAY 1 MAXIMUM PHASE OPPORTUNITY

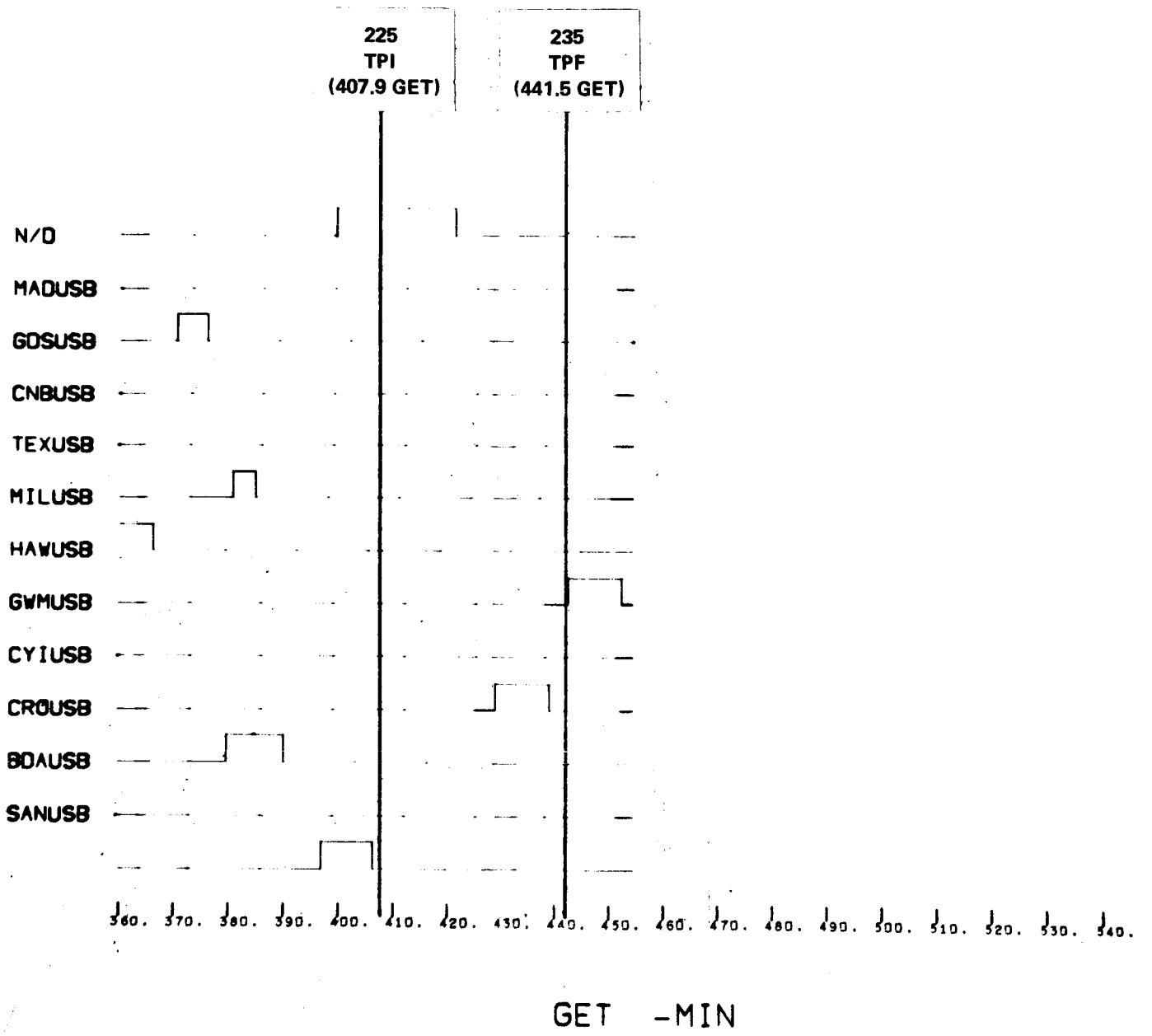


FIGURE 5 - SL-2 M = 5 DAY 1 MAXIMUM PHASE OPPORTUNITY

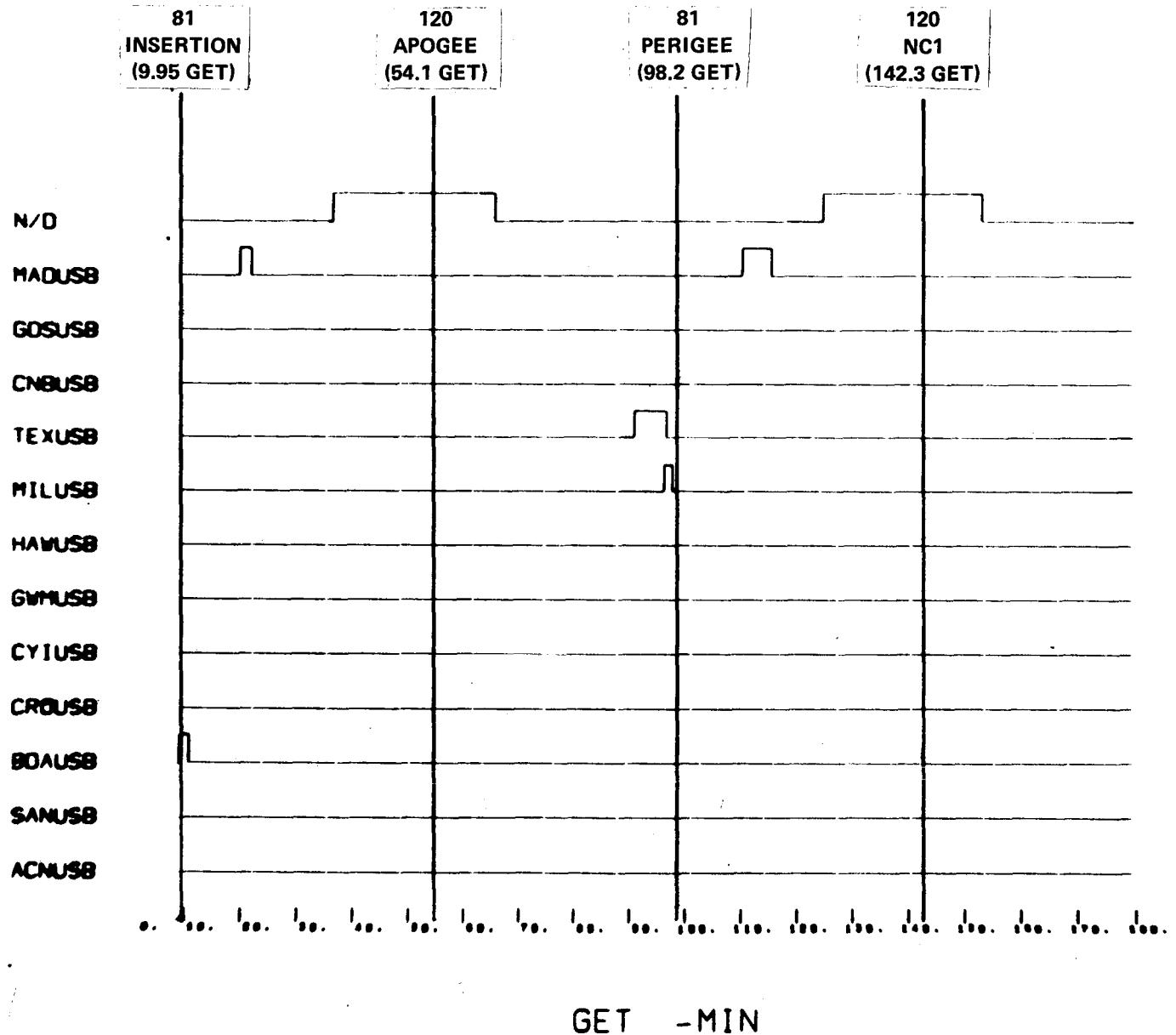
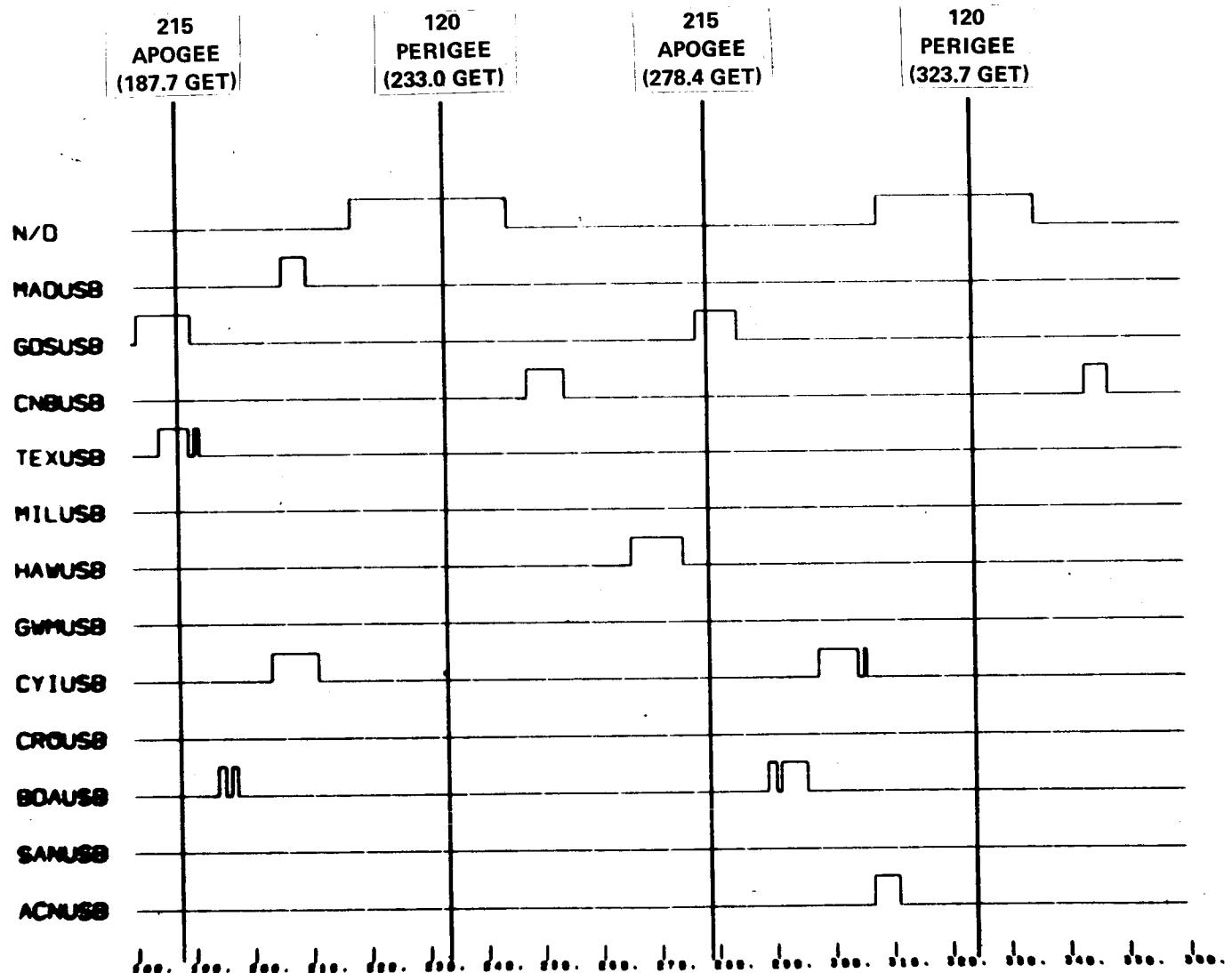
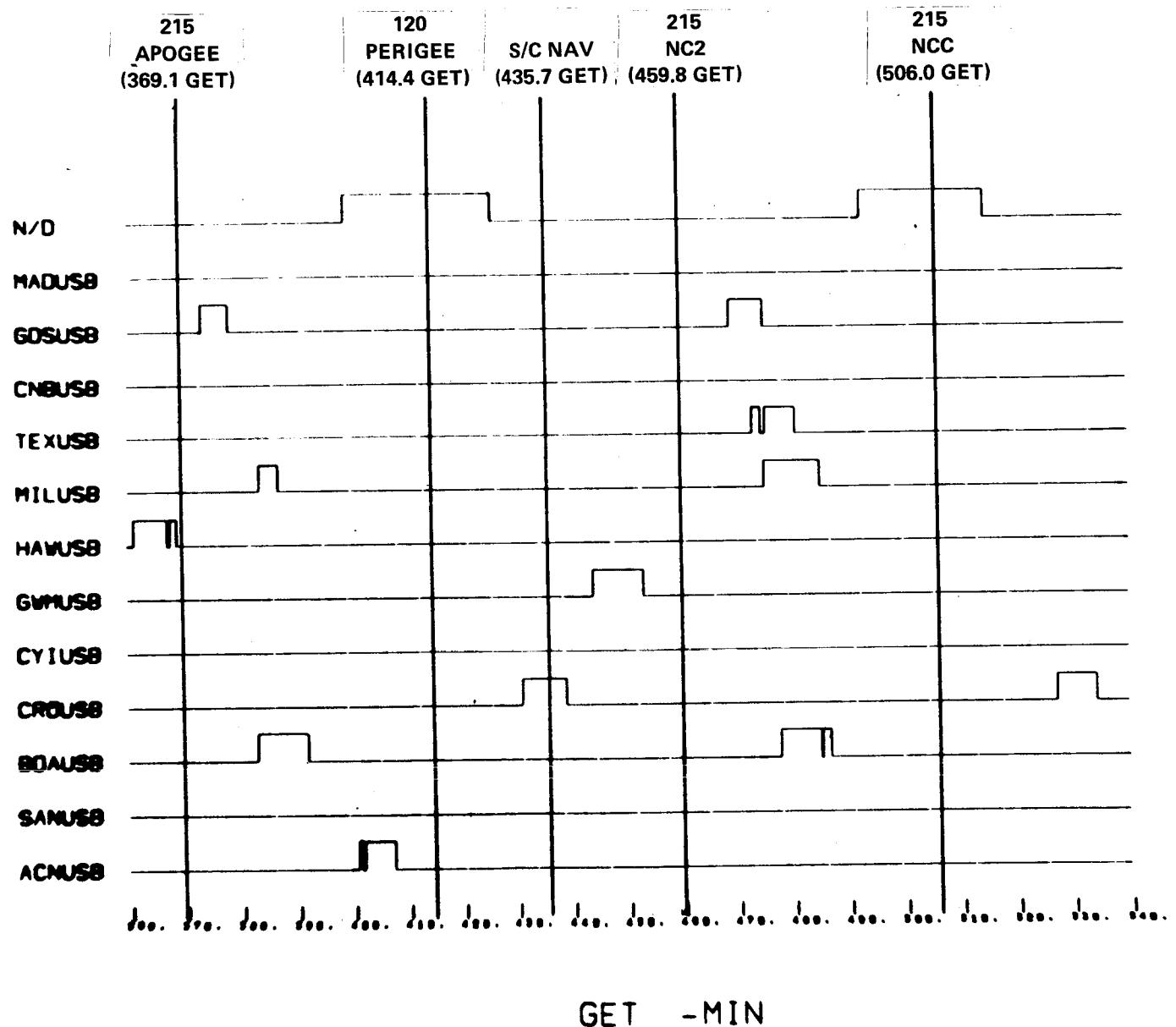


FIGURE 6 - SL-2 M = 7 DAY 1 MINIMUM PHASE OPPORTUNITY



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FIGURE 6 - SL-2 M = 7 DAY 1 MINIMUM PHASE OPPORTUNITY



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FIGURE 6 - SL-2 M = 7 DAY 1 MINIMUM PHASE OPPORTUNITY

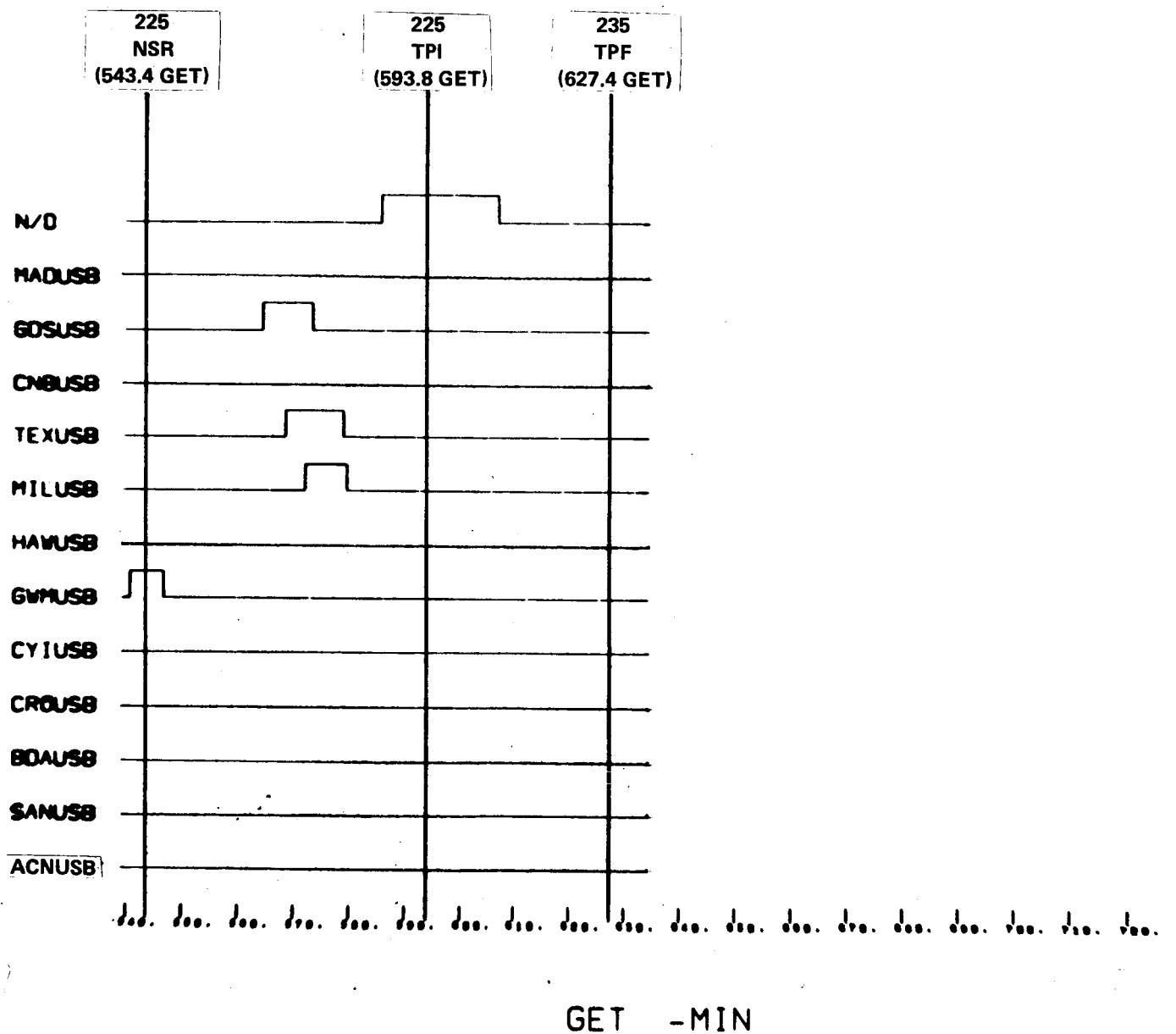


FIGURE 6 - SL-2 M = 7 DAY 1 MINIMUM PHASE OPPORTUNITY

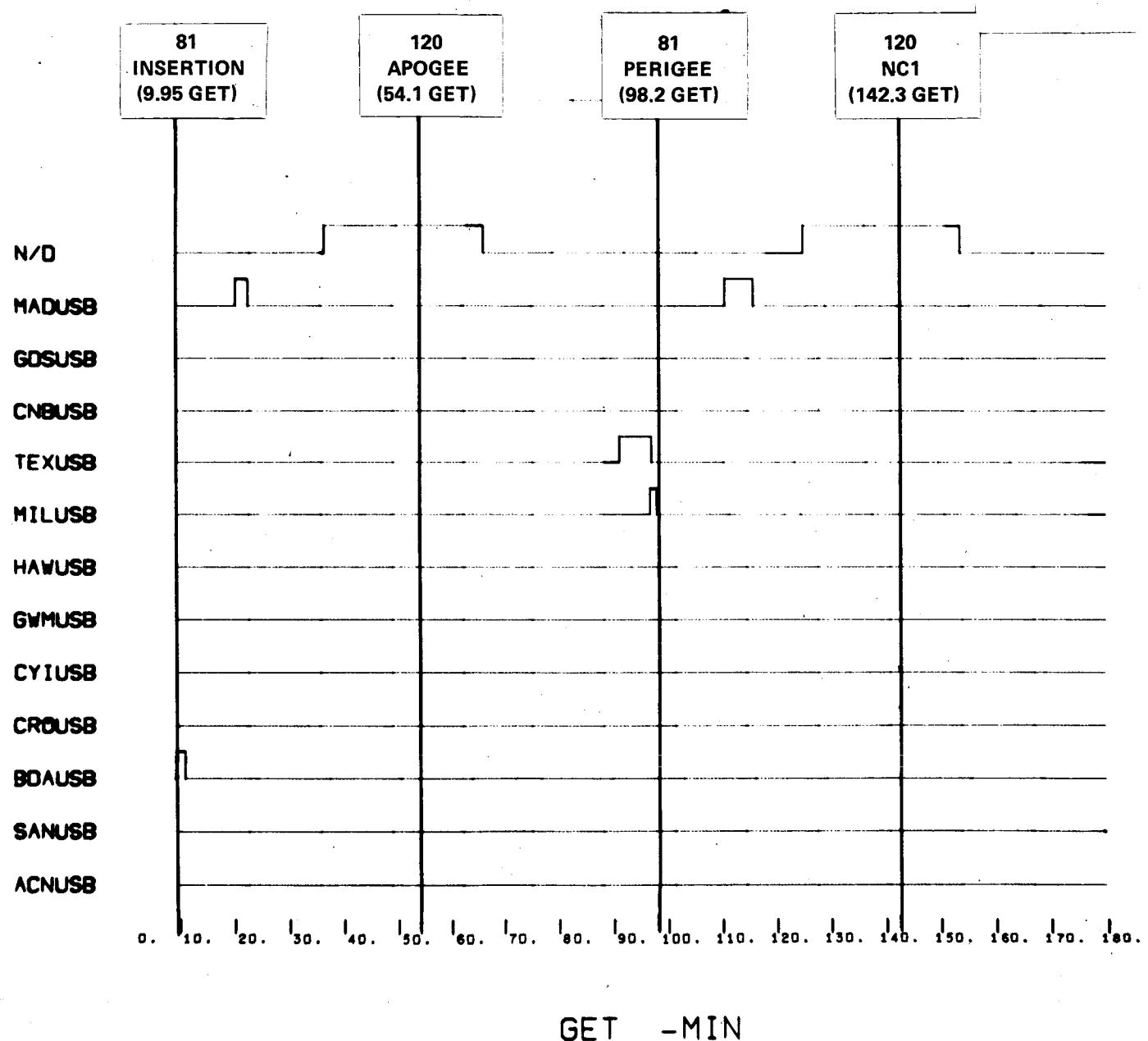


FIGURE 7 - SL-2 M = 6 DAY 1 AVERAGE PHASE OPPORTUNITY

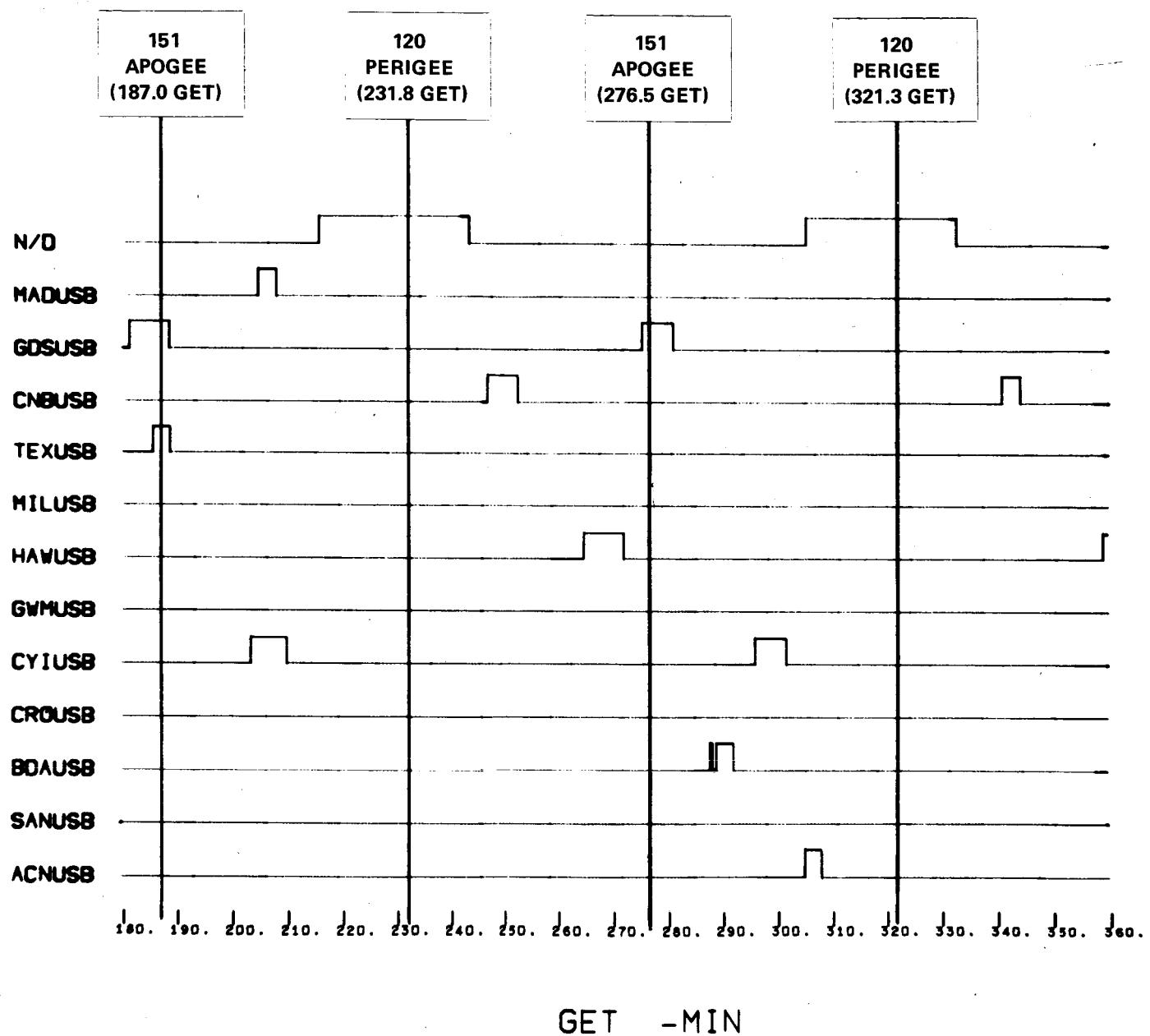


FIGURE 7 - SL-2 M = 6 DAY 1 AVERAGE PHASE OPPORTUNITY

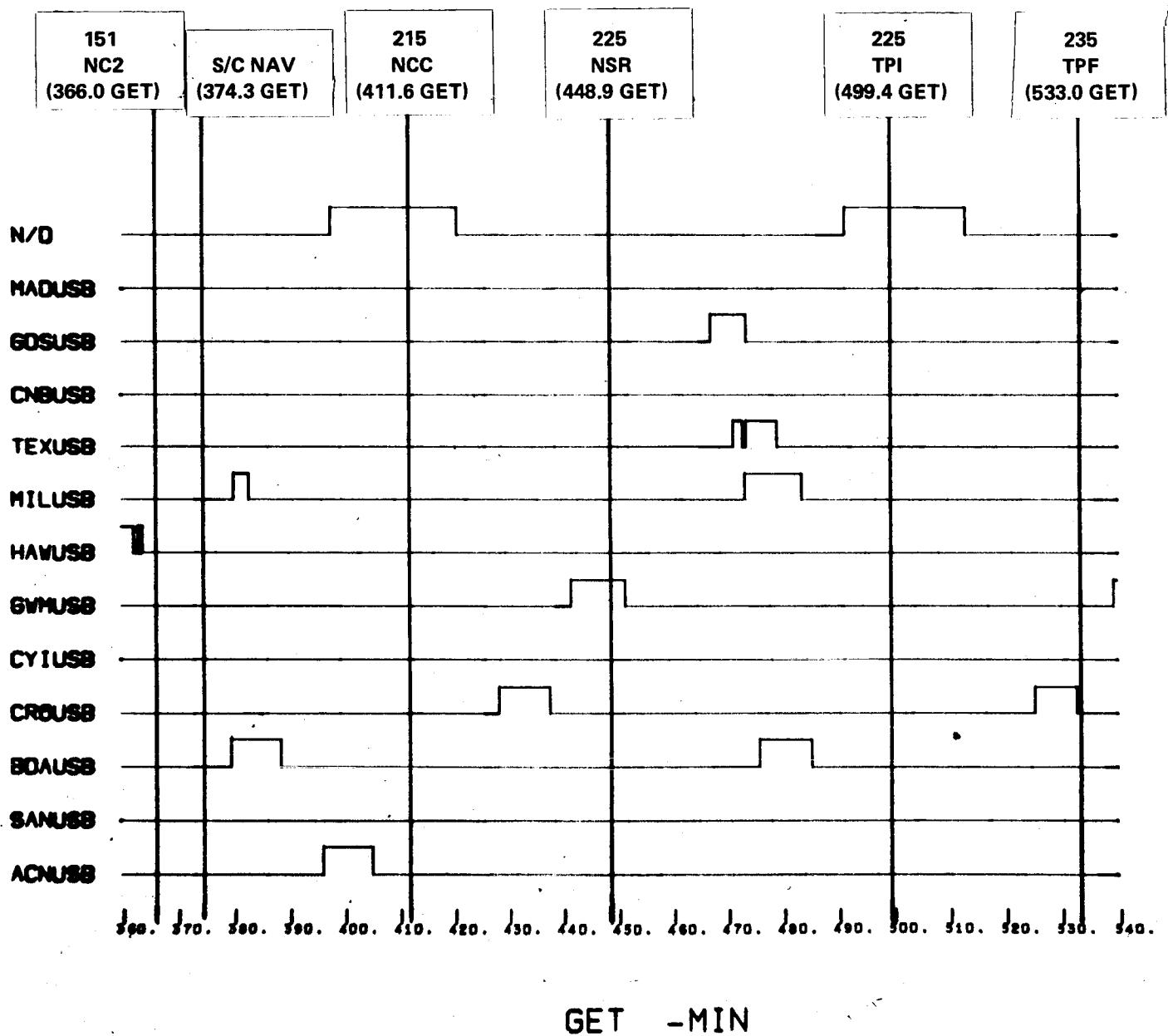


FIGURE 7 - SL-2 M = 6 DAY 1 AVERAGE PHASE OPPORTUNITY

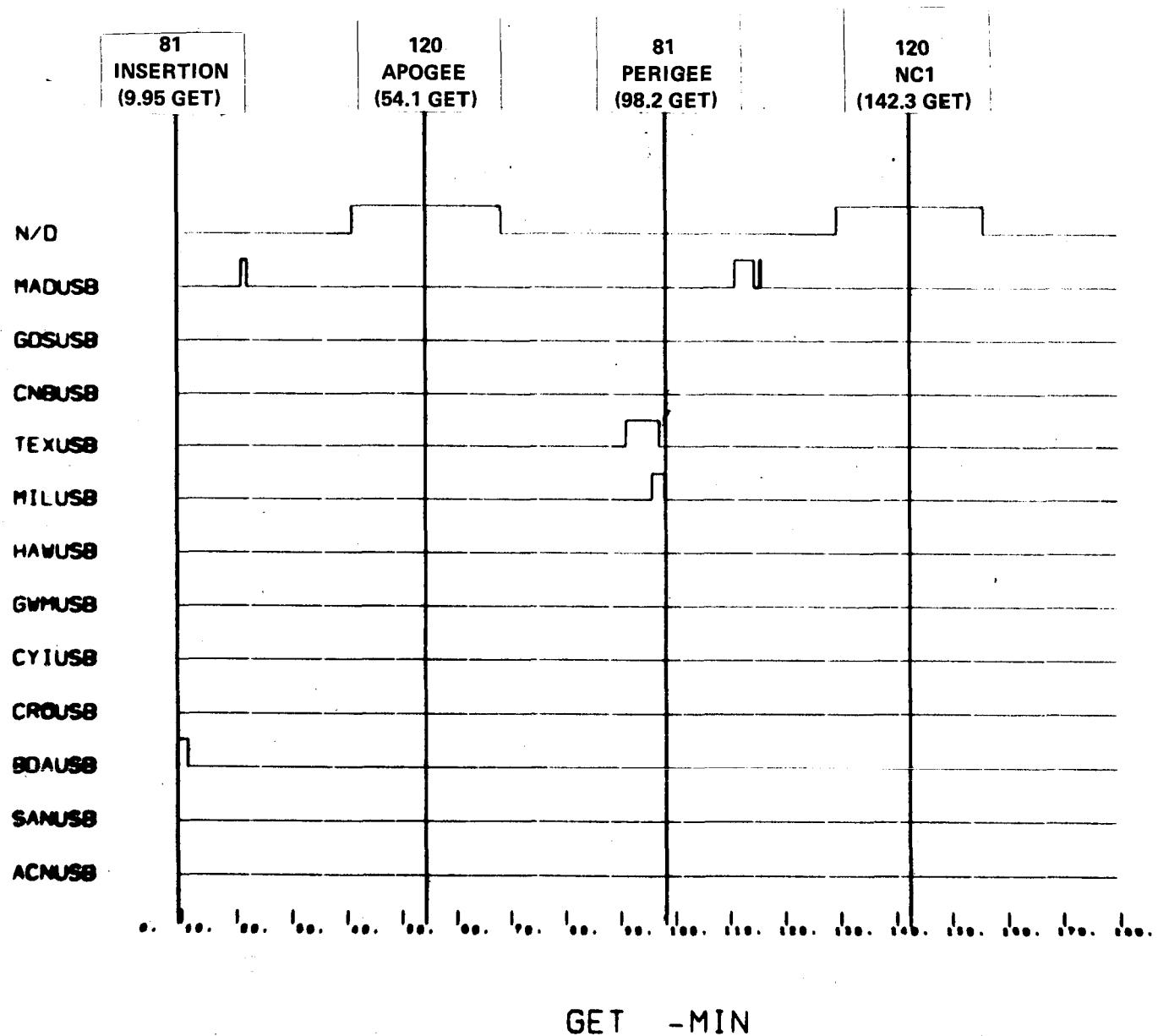


FIGURE 8 - SL-2 M = 8 DAY 2 AVERAGE PHASE OPPORTUNITY

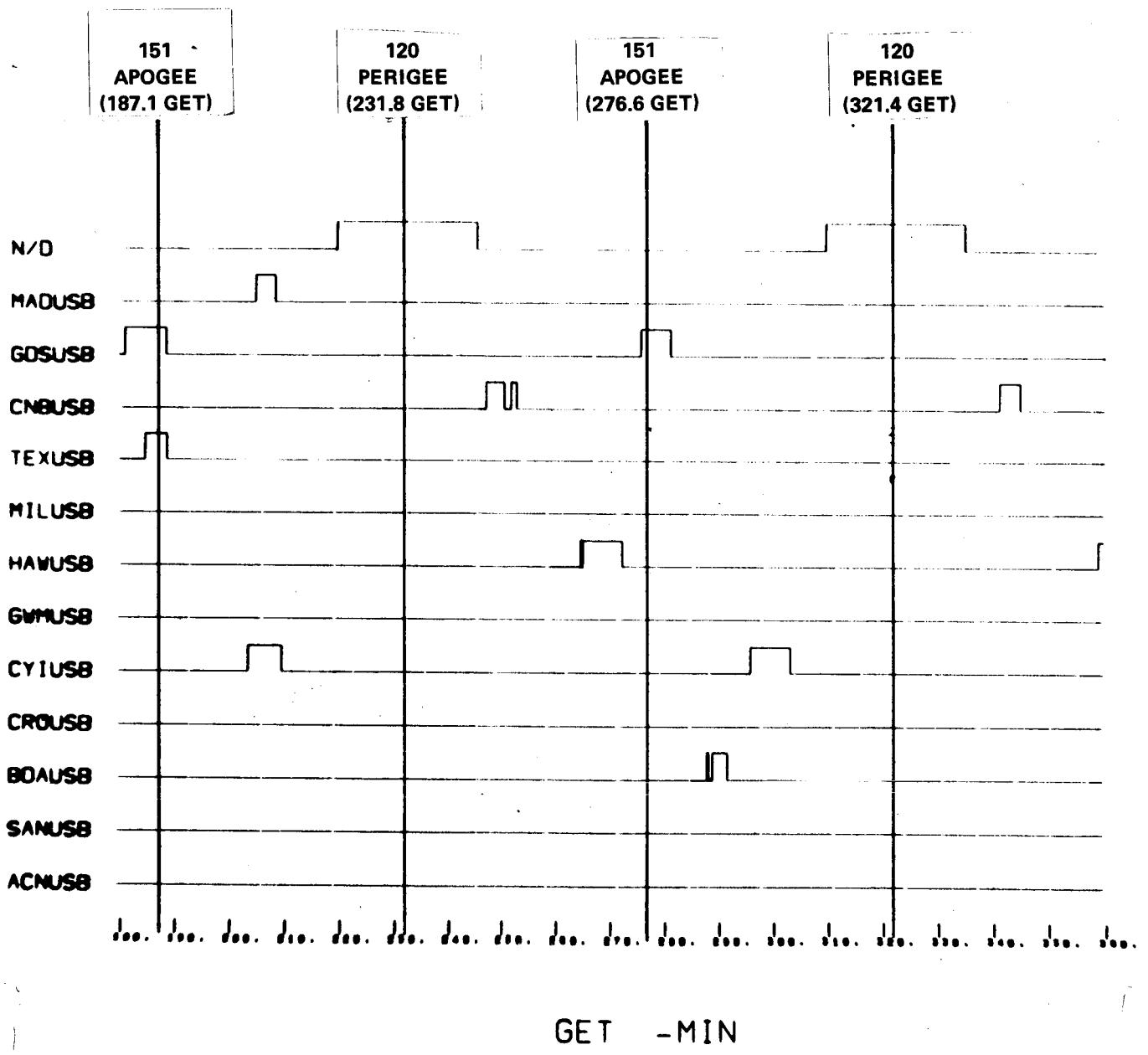


FIGURE 8 - SL-2 M = 8 DAY 2 AVERAGE PHASE OPPORTUNITY

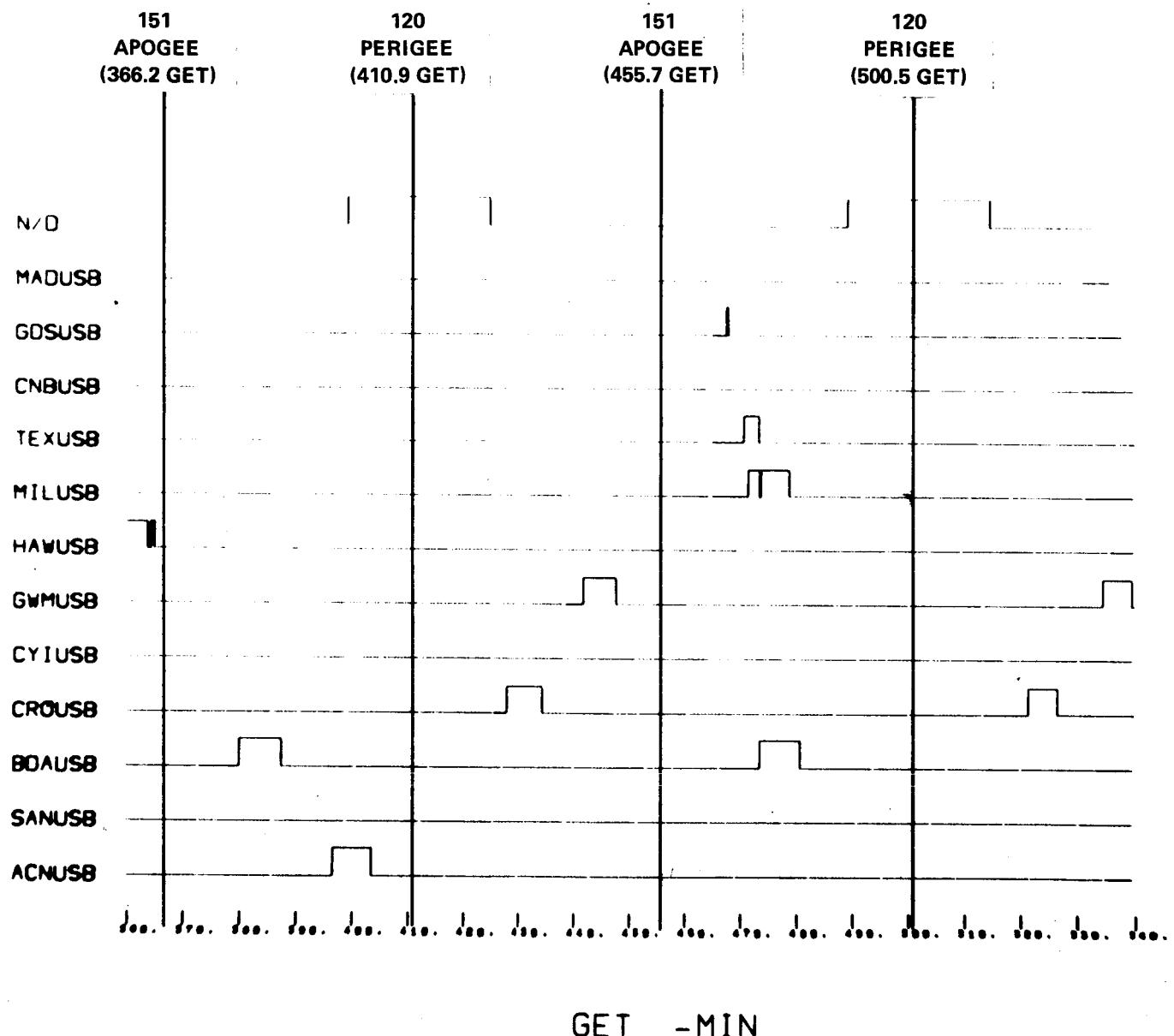
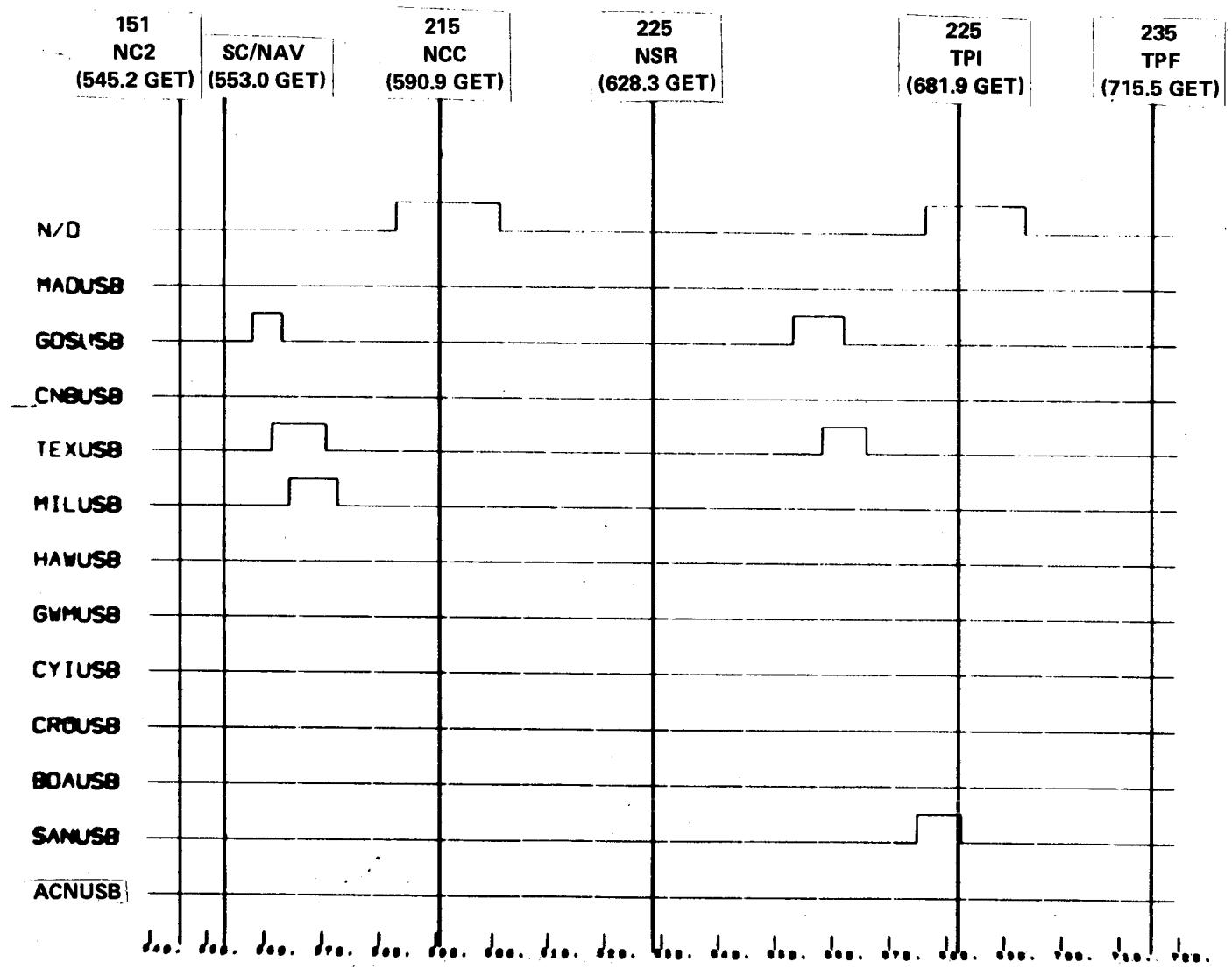


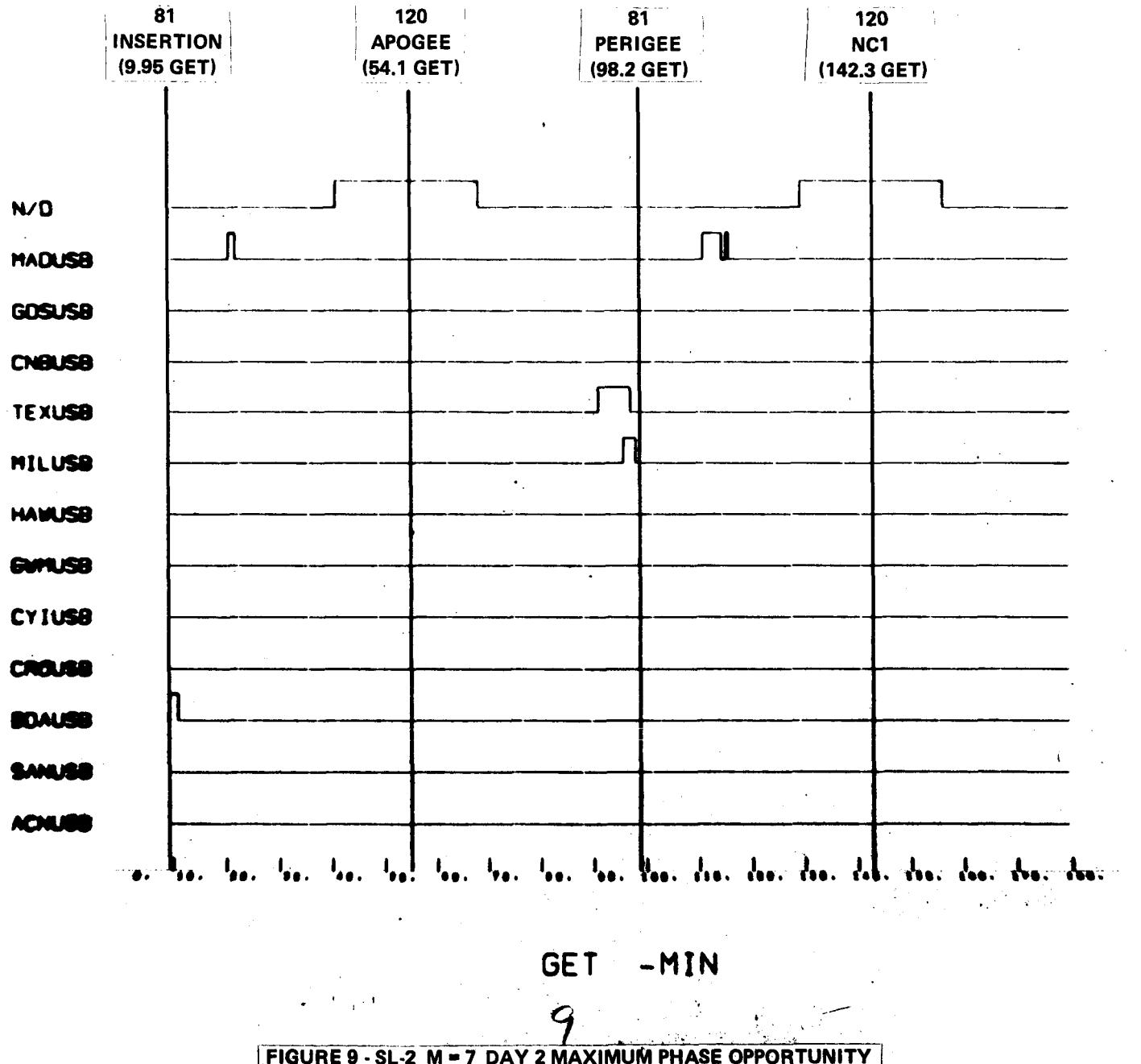
FIGURE 8 - SL-2 M = 8 DAY 2 AVERAGE PHASE OPPORTUNITY



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FIGURE 8 - SL-2 M = 8 DAY 2 AVERAGE PHASE OPPORTUNITY



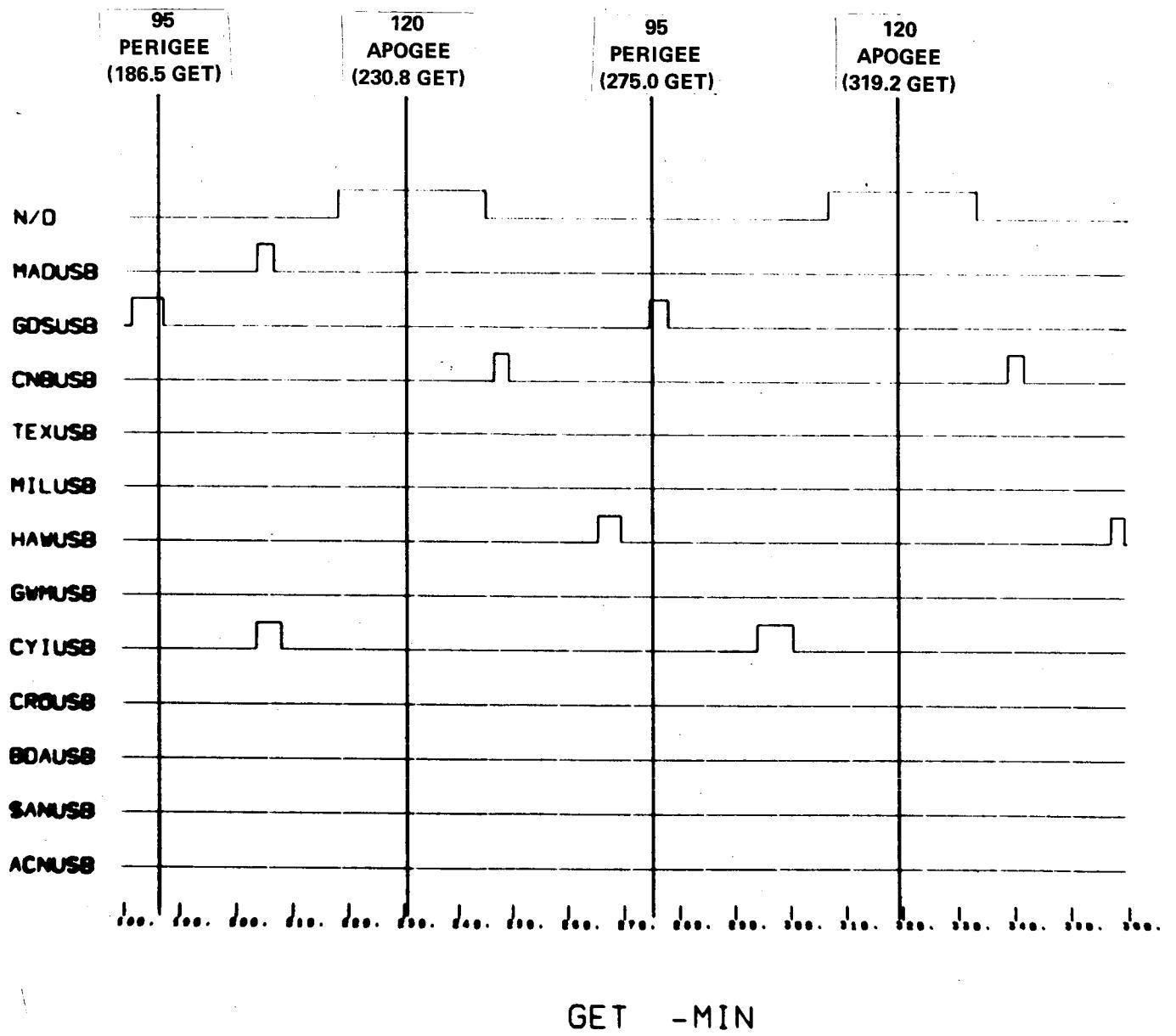
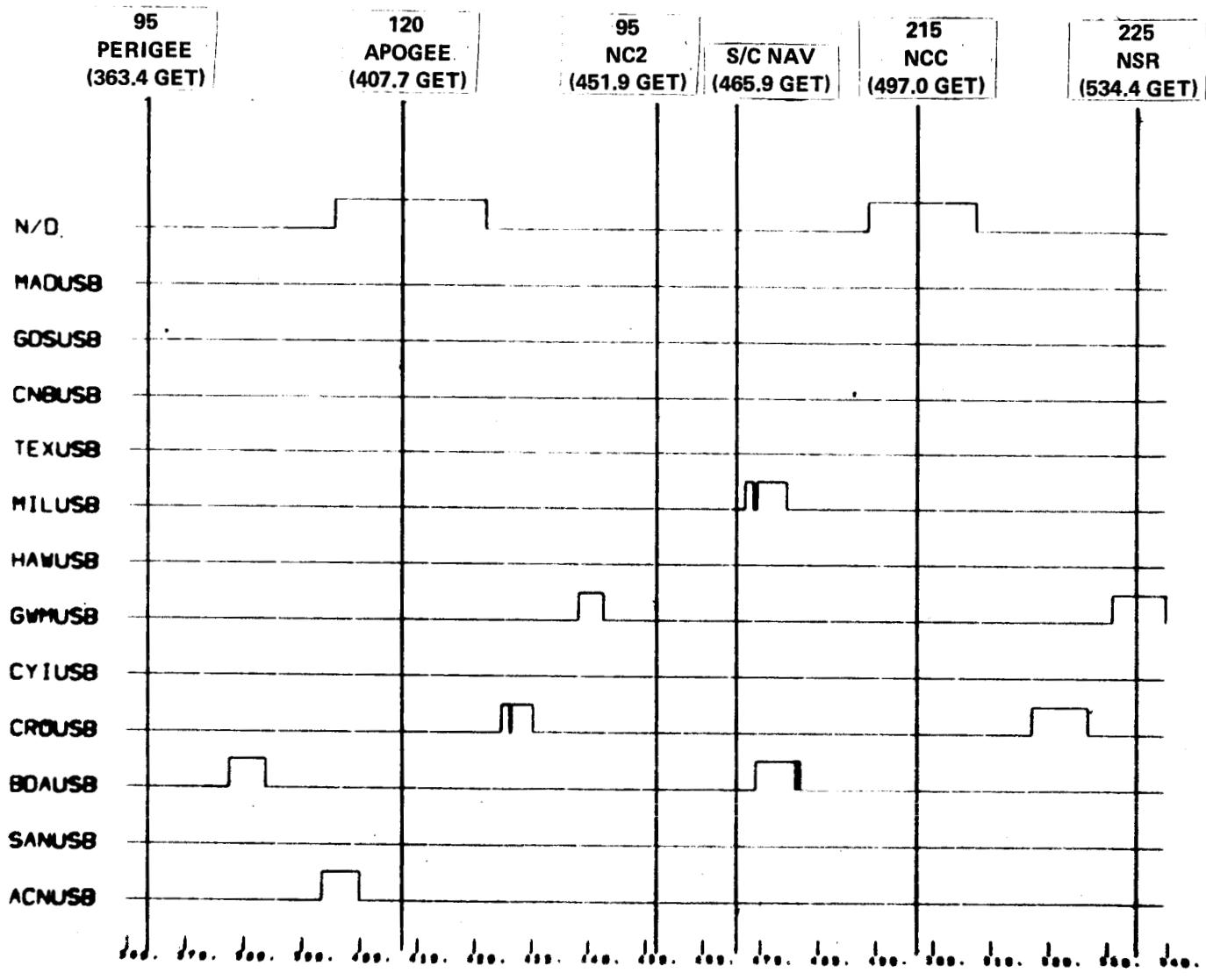
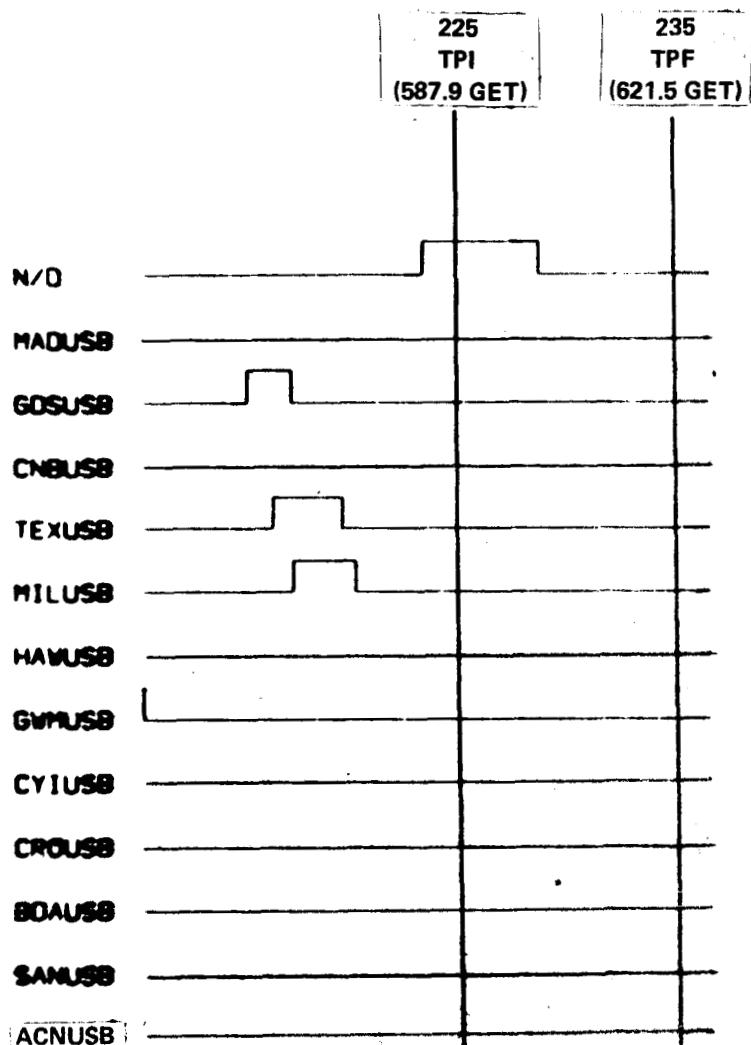


FIGURE 9 - SL-2 M = 7 DAY 2 MAXIMUM PHASE OPPORTUNITY



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FIGURE 9 - SL-2 M = 7 DAY 2 MAXIMUM PHASE OPPORTUNITY



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FIGURE 9 - SL-2 M=7 DAY 2 MAXIMUM PHASE OPPORTUNITY

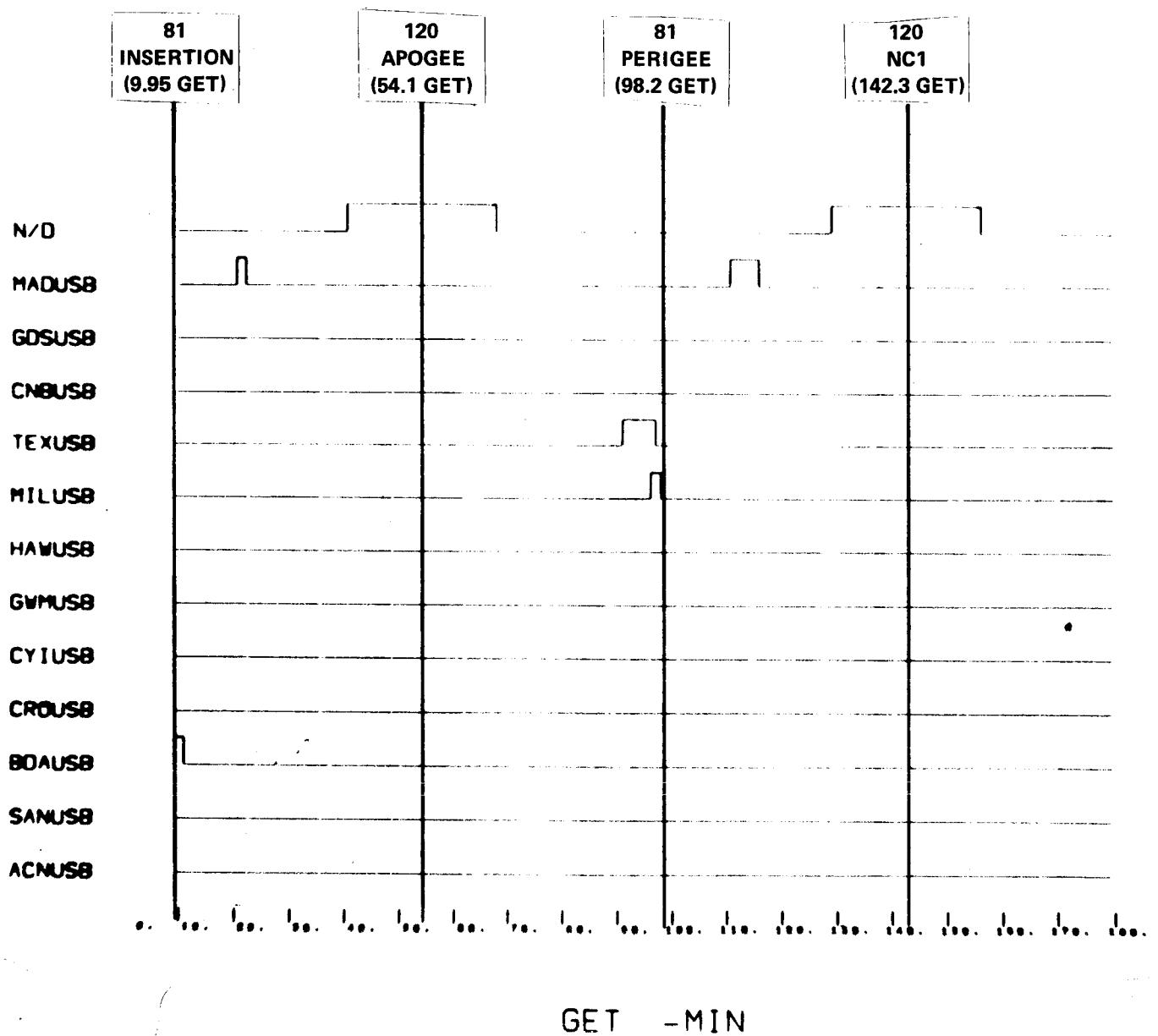


FIGURE 10 - SL-2 M - 8 DAY 2 MAXIMUM PHASE OPPORTUNITY

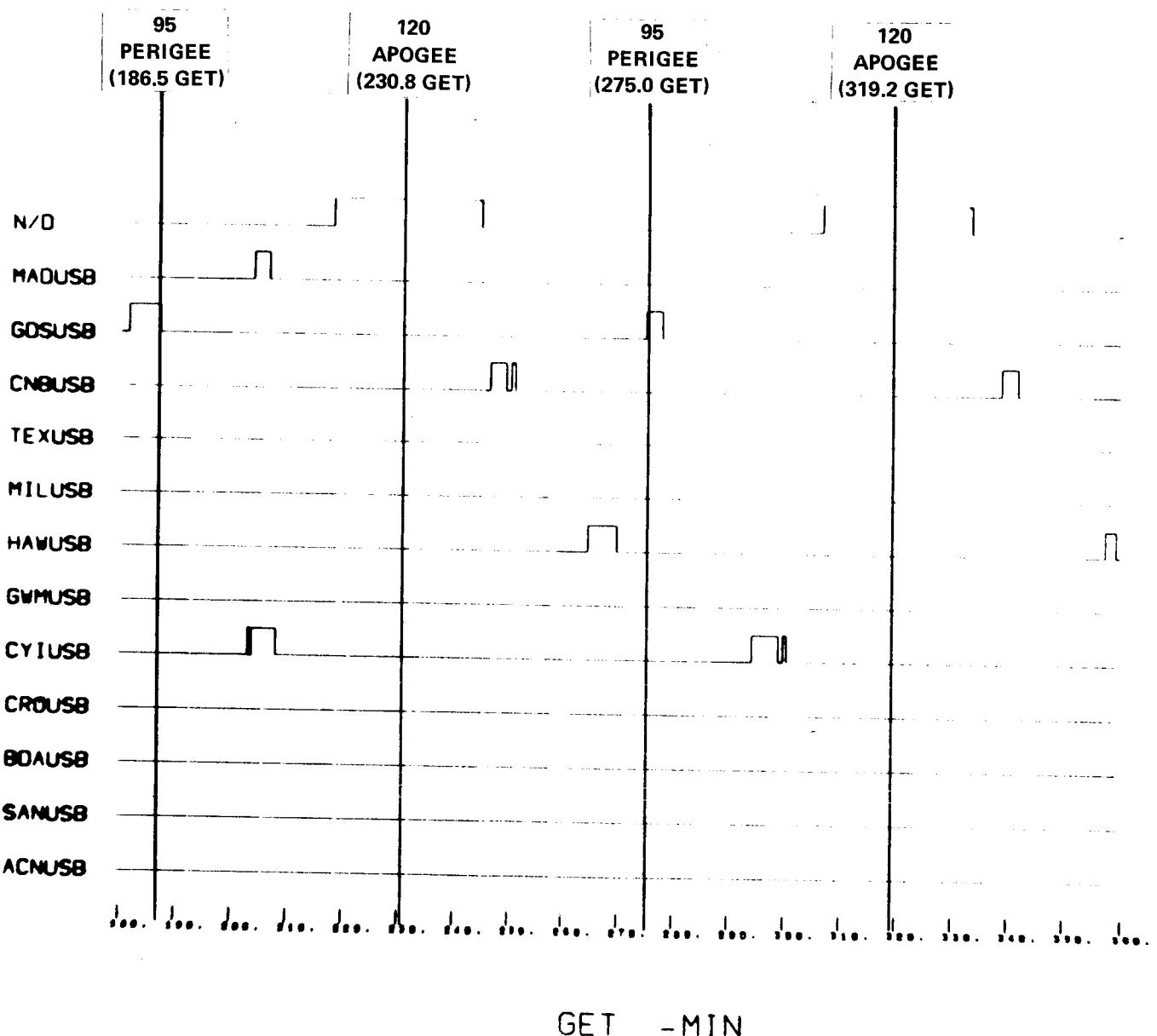


FIGURE 10 - SL-2 M = 8 DAY 2 MAXIMUM PHASE OPPORTUNITY

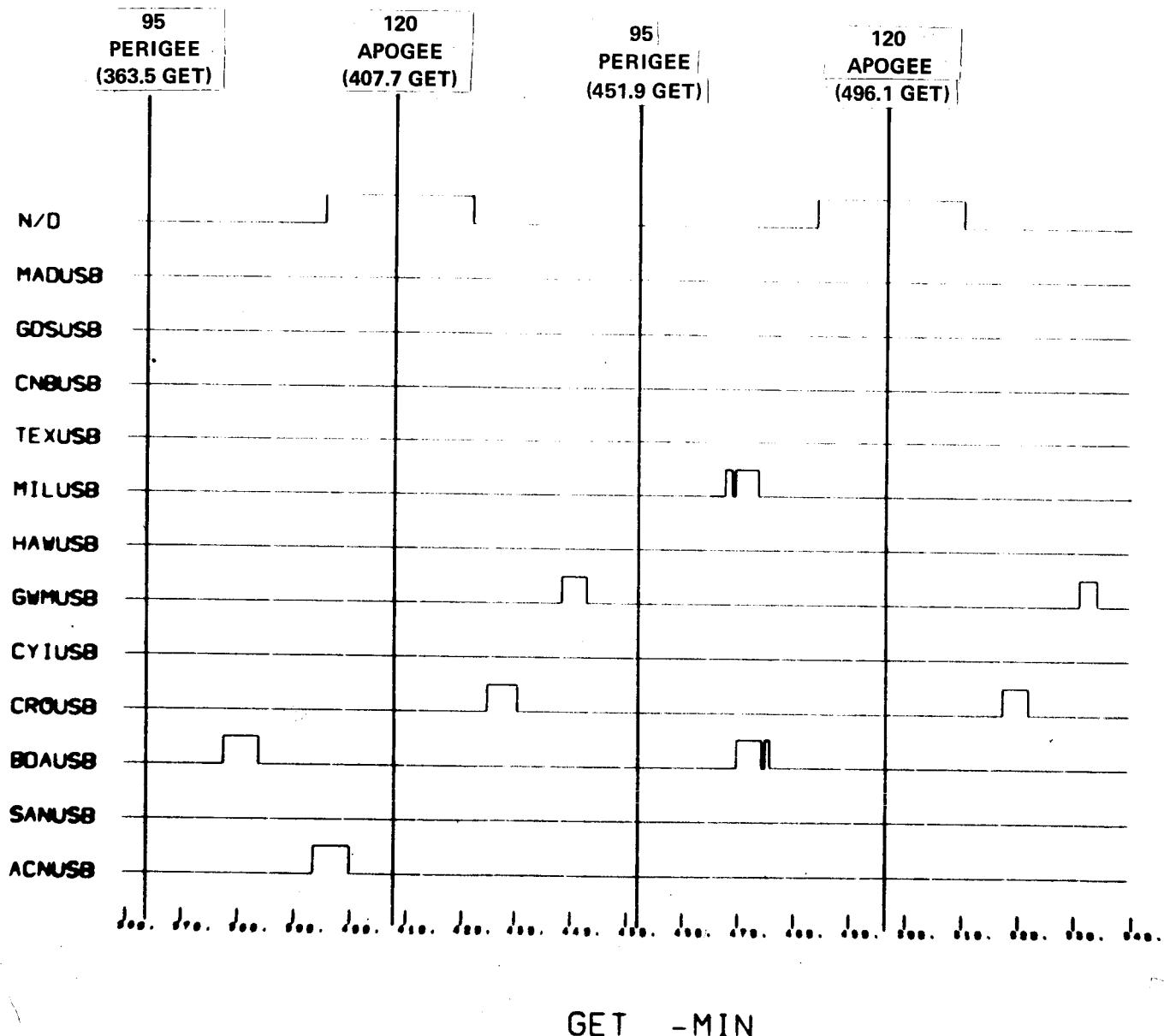


FIGURE 10 - SL-2 M = 8 DAY 2 MAXIMUM PHASE OPPORTUNITY

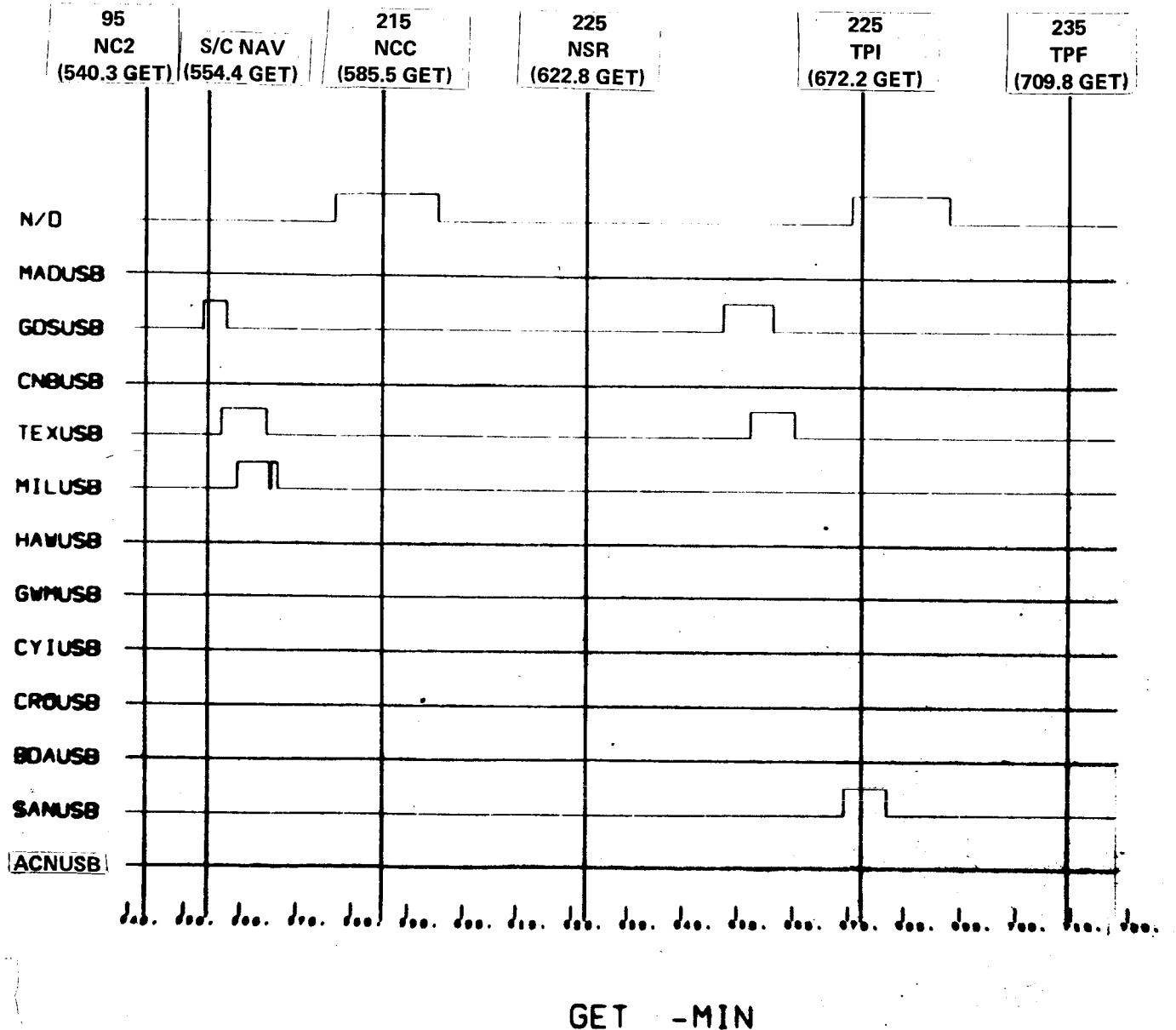


FIGURE 10 - SL-2 M = 8 DAY 2 MAXIMUM PHASE OPPORTUNITY

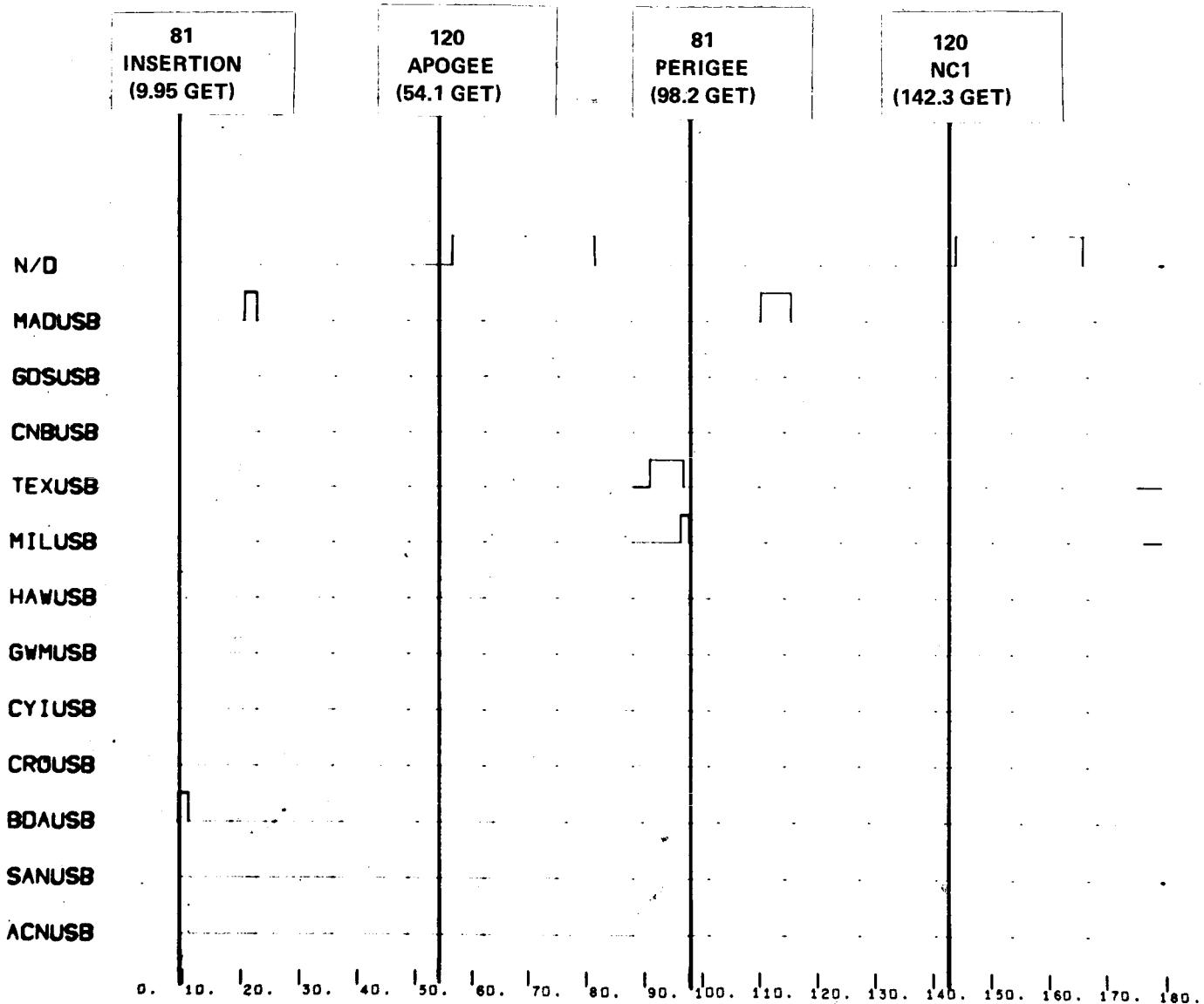


FIGURE 11 - SL-2 M = 5 DAY 6 MINIMUM PHASE OPPORTUNITY

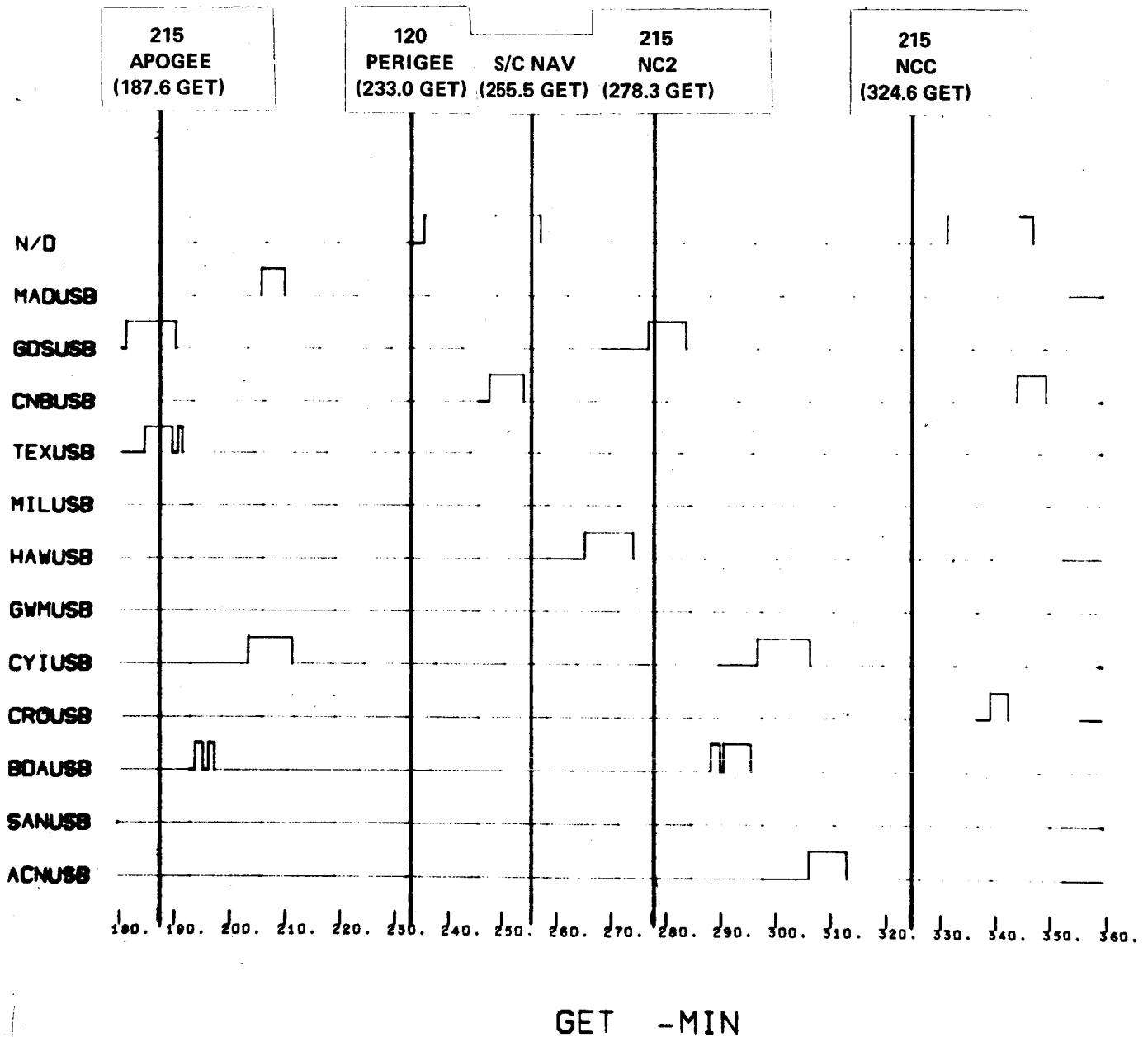


FIGURE 11 - SL-2 M = 5 DAY 6 MINIMUM PHASE OPPORTUNITY

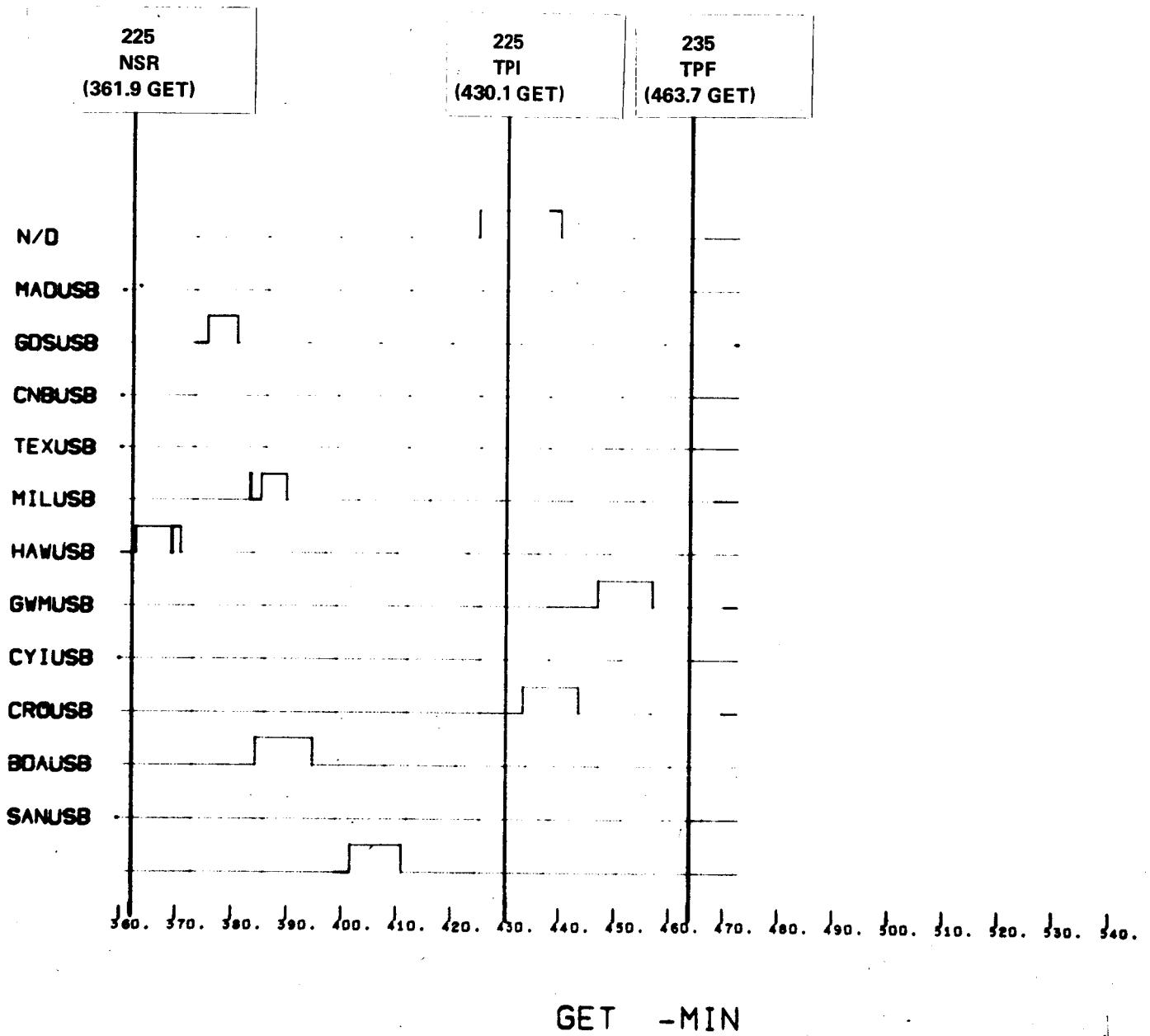


FIGURE 11-6L-2-M= 5 DAY 6 MINIMUM PHASE OPPORTUNITY

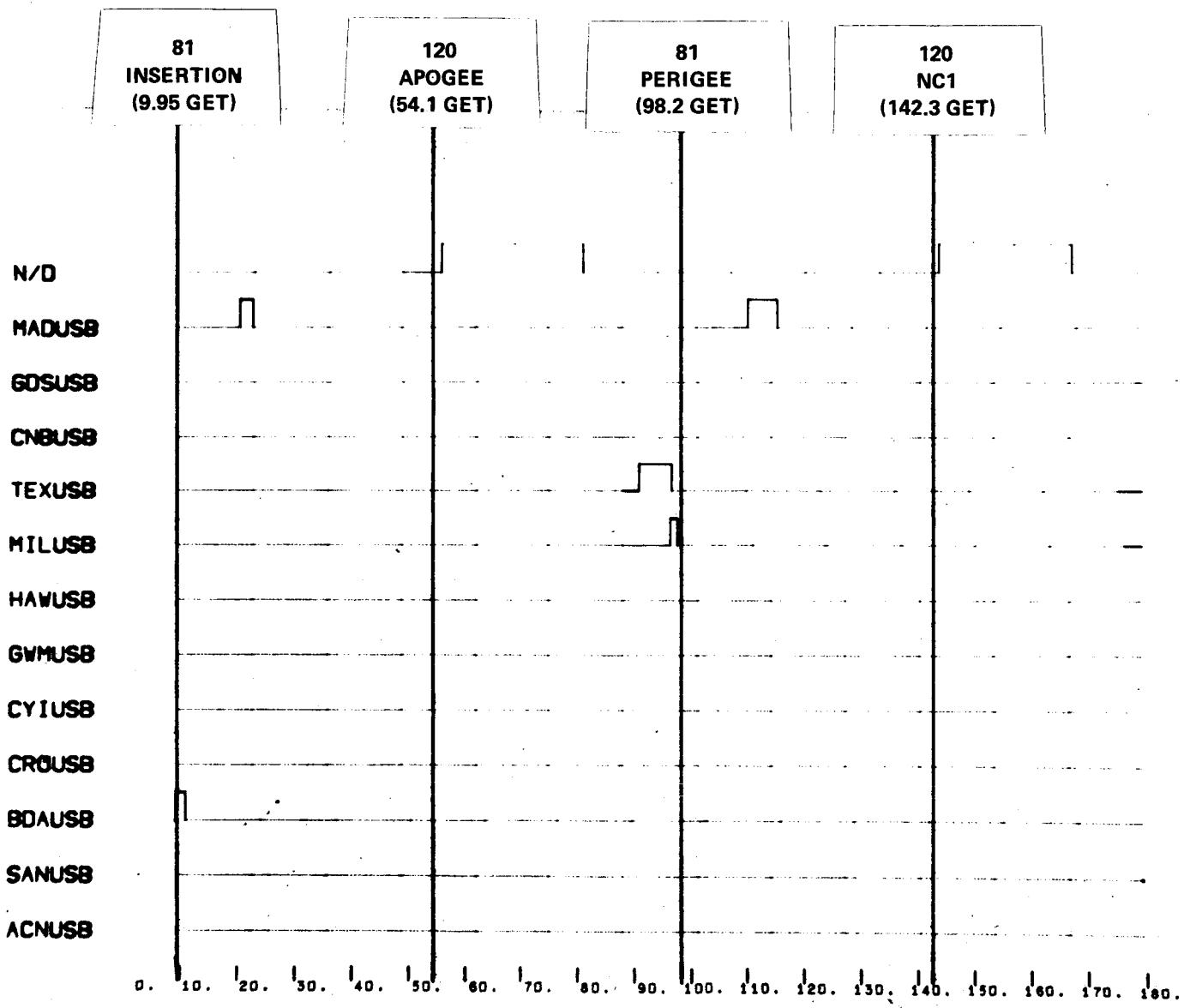
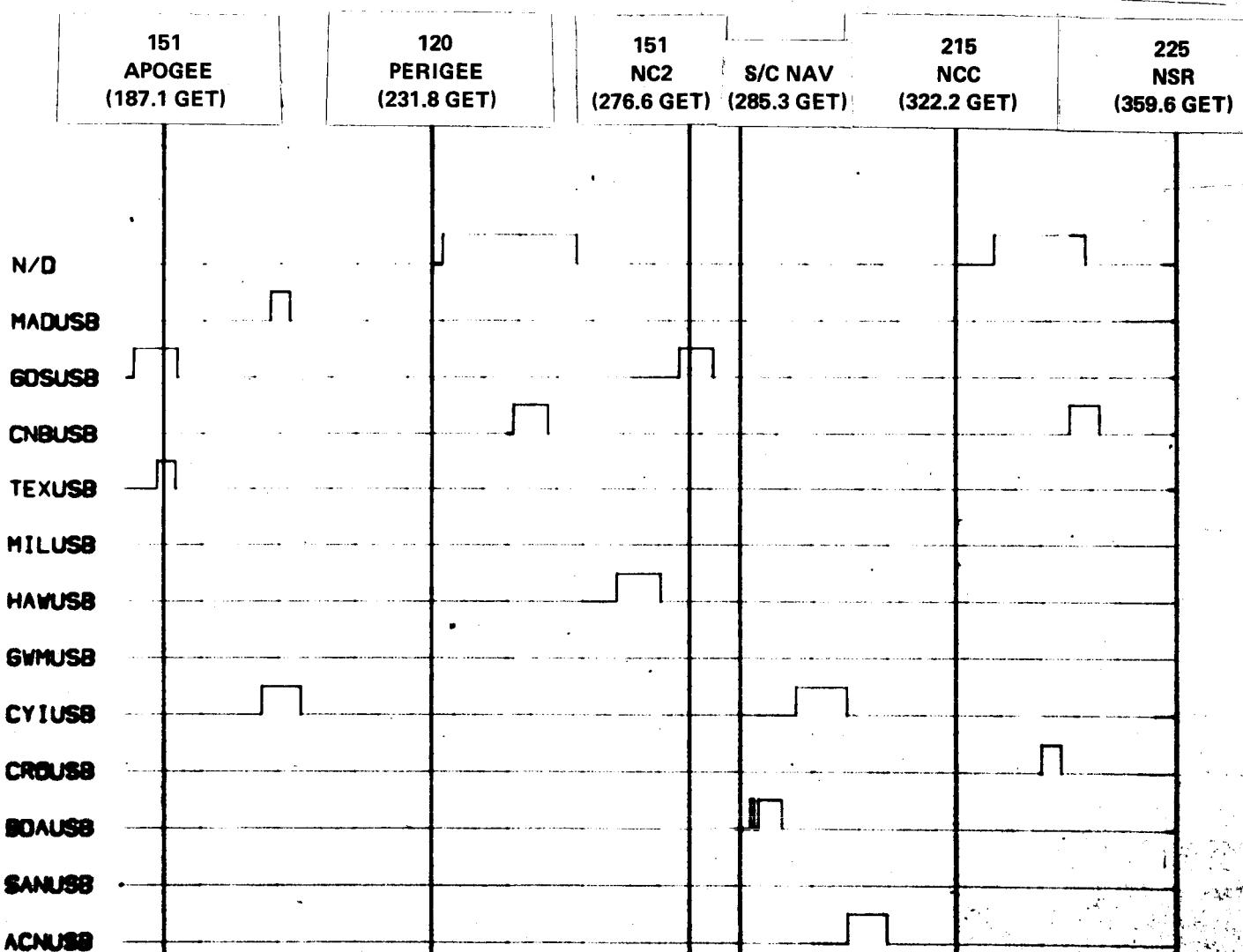


FIGURE 12-SL-2 M = 5 DAY 6 AVERAGE PHASE OPPORTUNITY



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FIGURE 12 - SL-2 M = 5 DAY 6 AVERAGE PHASE OPPORTUNITY

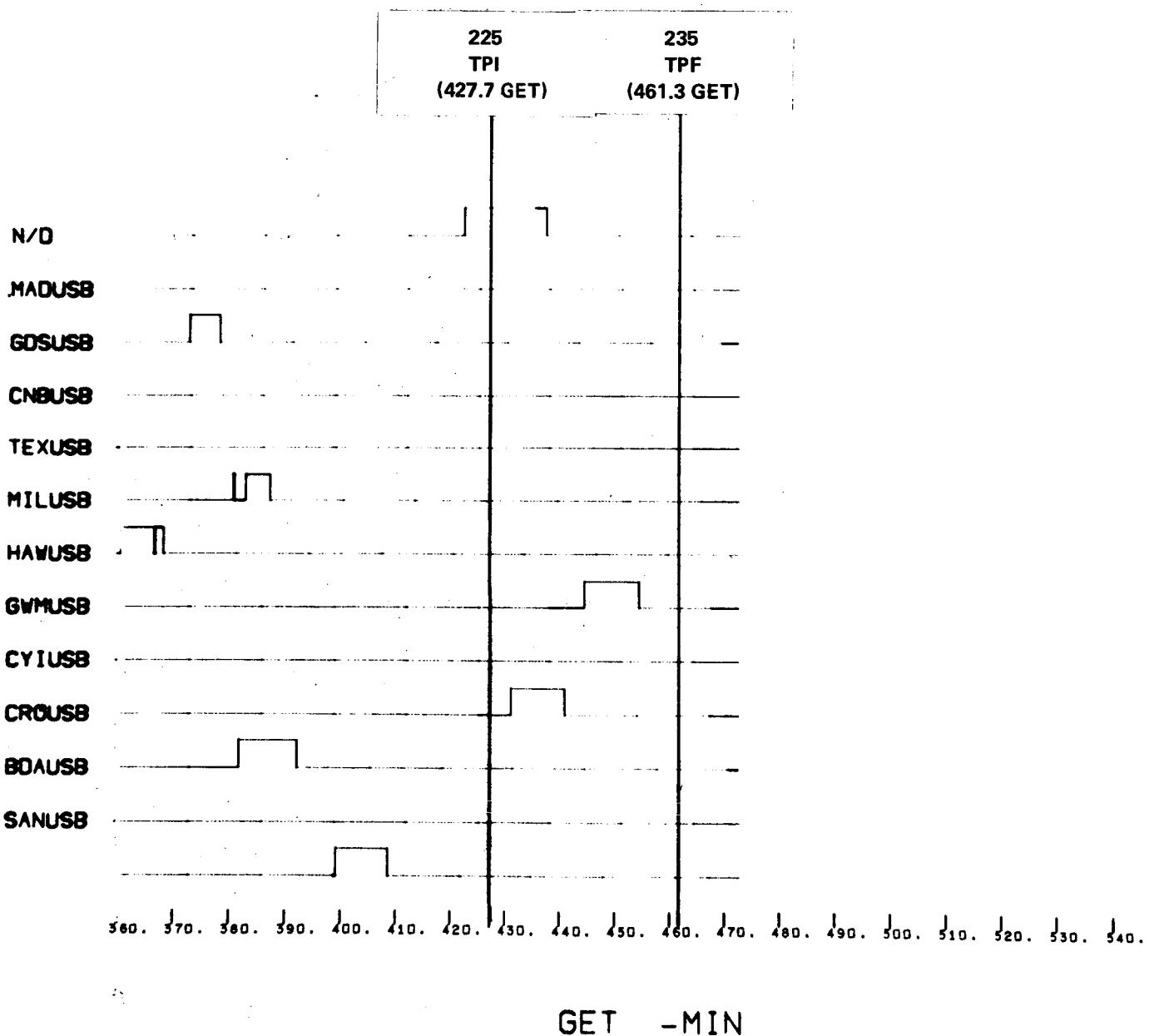
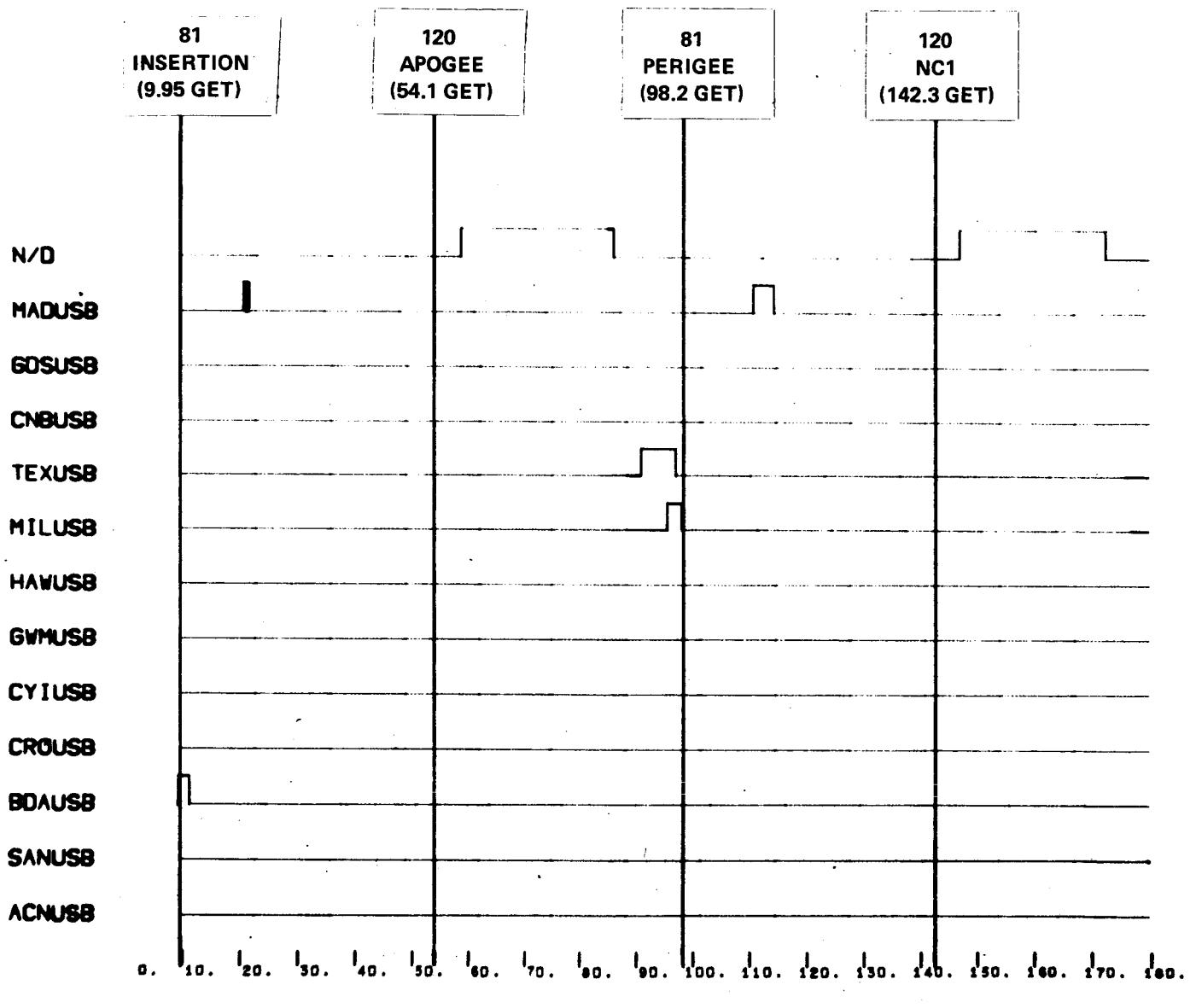
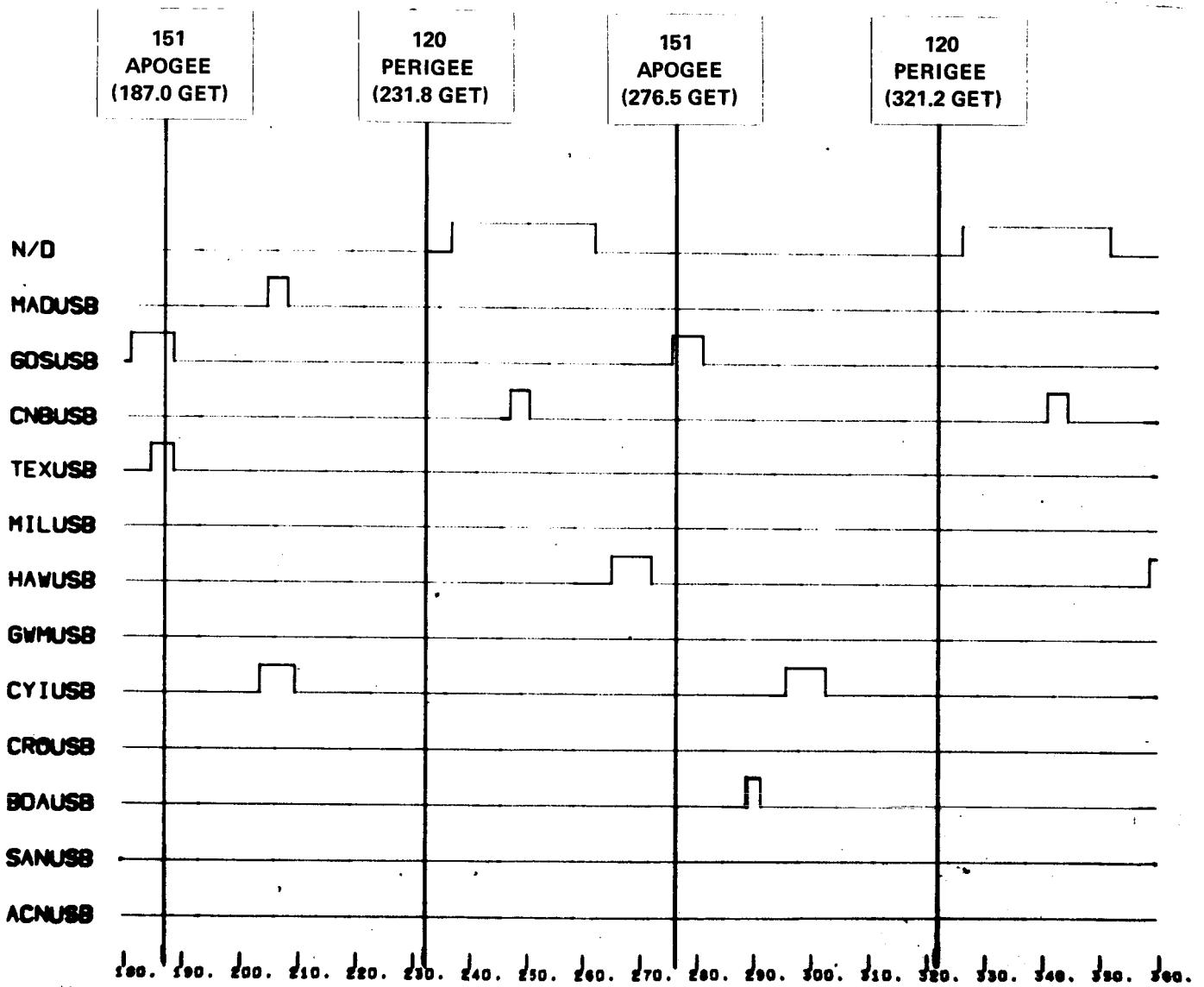


FIGURE 12 - SL-2 M = 6 DAY 6 AVERAGE PHASE OPPORTUNITY



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FIGURE 13 - SL-2 M = 6 DAY 7 AVERAGE PHASE OPPORTUNITY



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FIGURE 13 - SL-2 M = 6 DAY 7 AVERAGE PHASE OPPORTUNITY

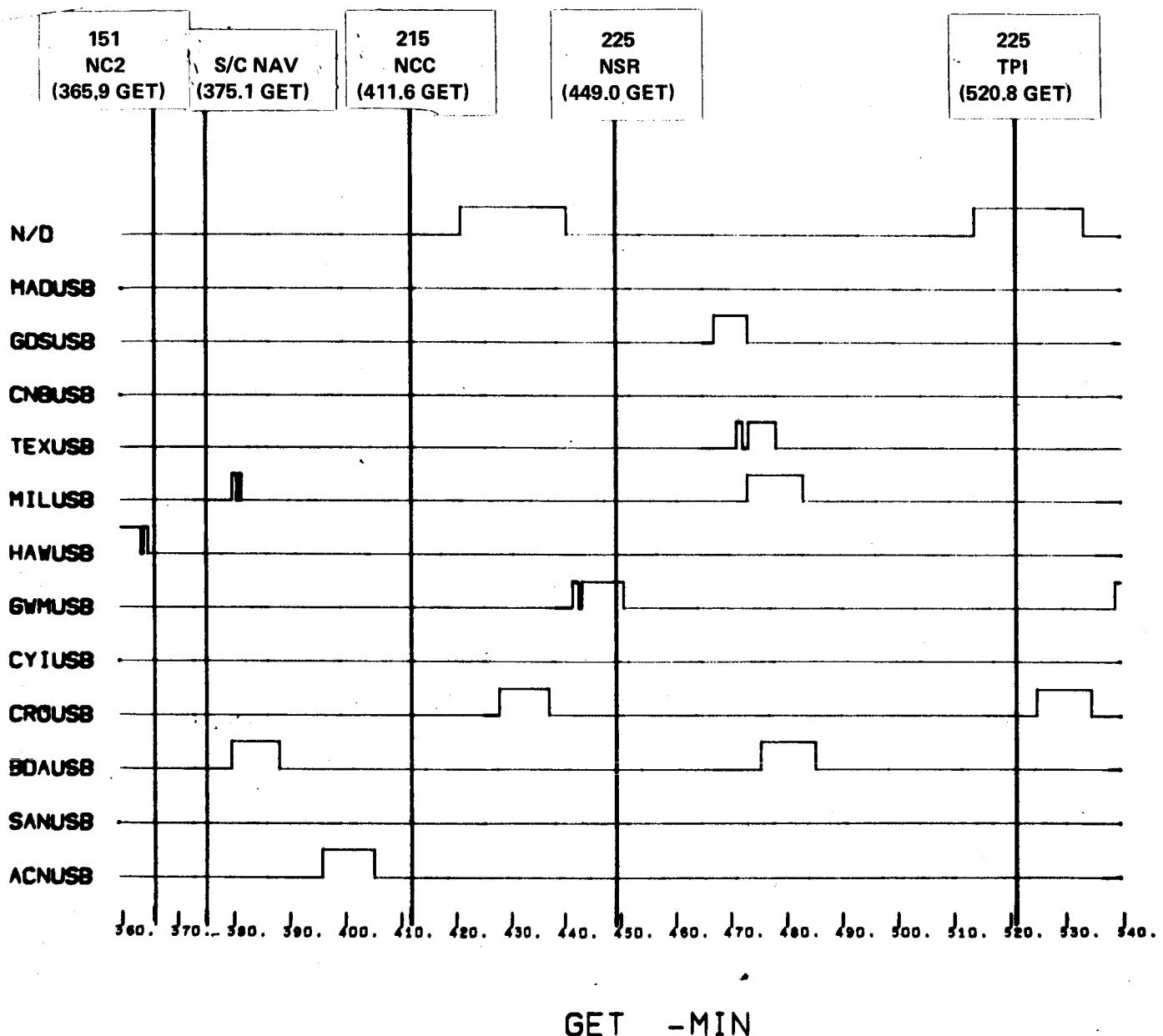
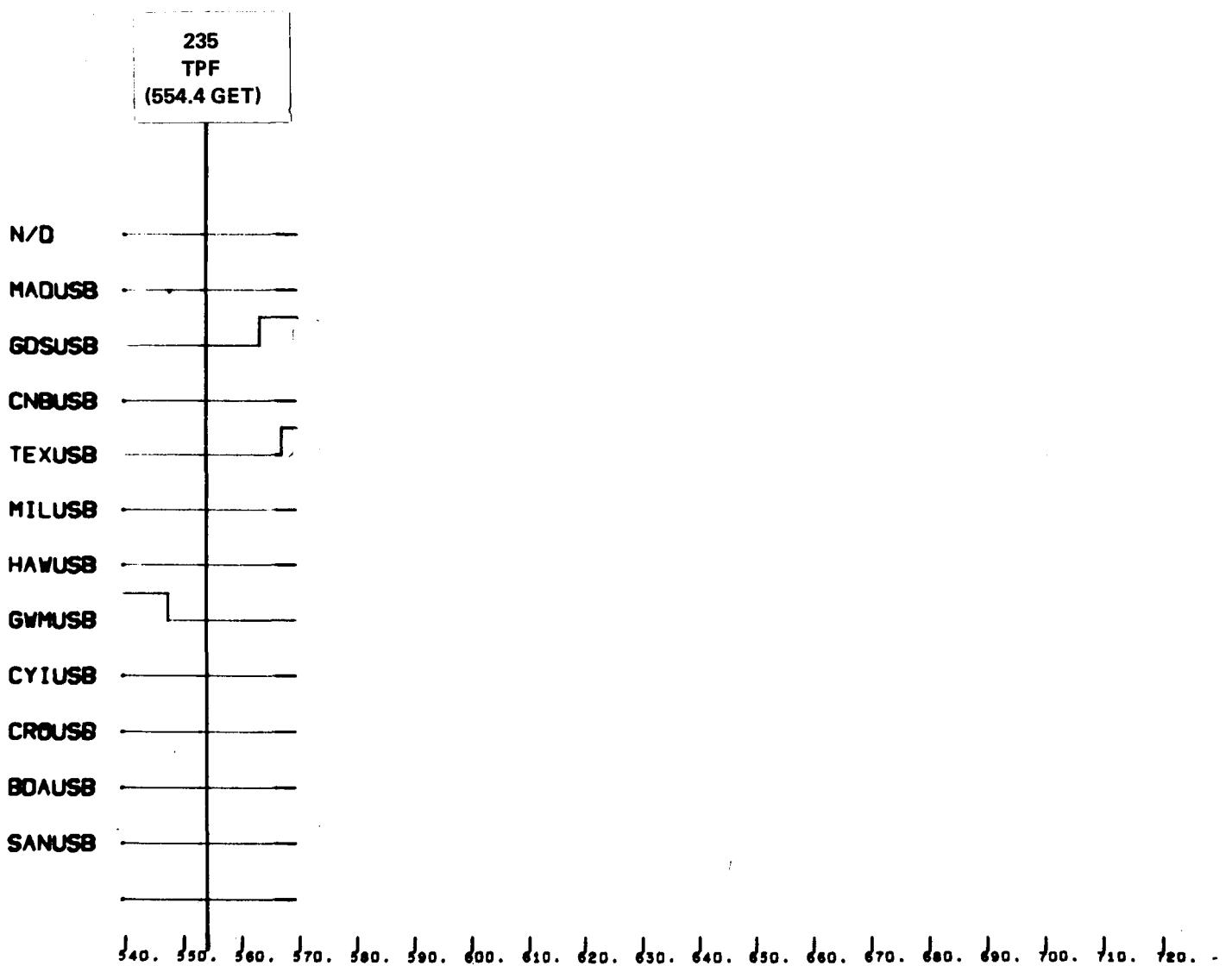


FIGURE 13 - SL-2 M - 6 DAY 7 AVERAGE PHASE OPPORTUNITY



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FIGURE 13 - SL-2 M - 6 DAY 7 AVERAGE PHASE OPPORTUNITY

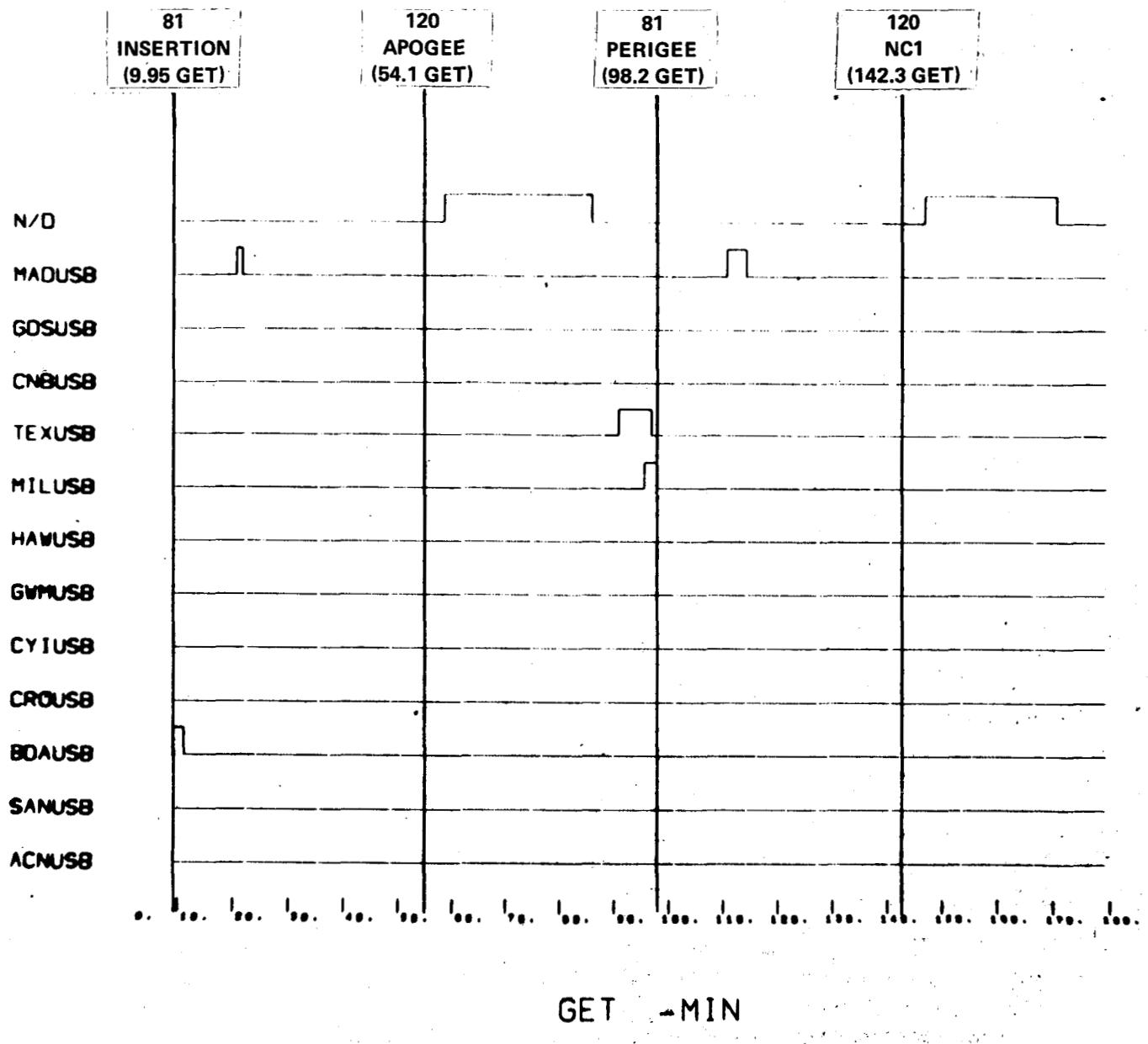


FIGURE 14 - SL-2 M = 8 DAY 7 MINIMUM PHASE OPPORTUNITY

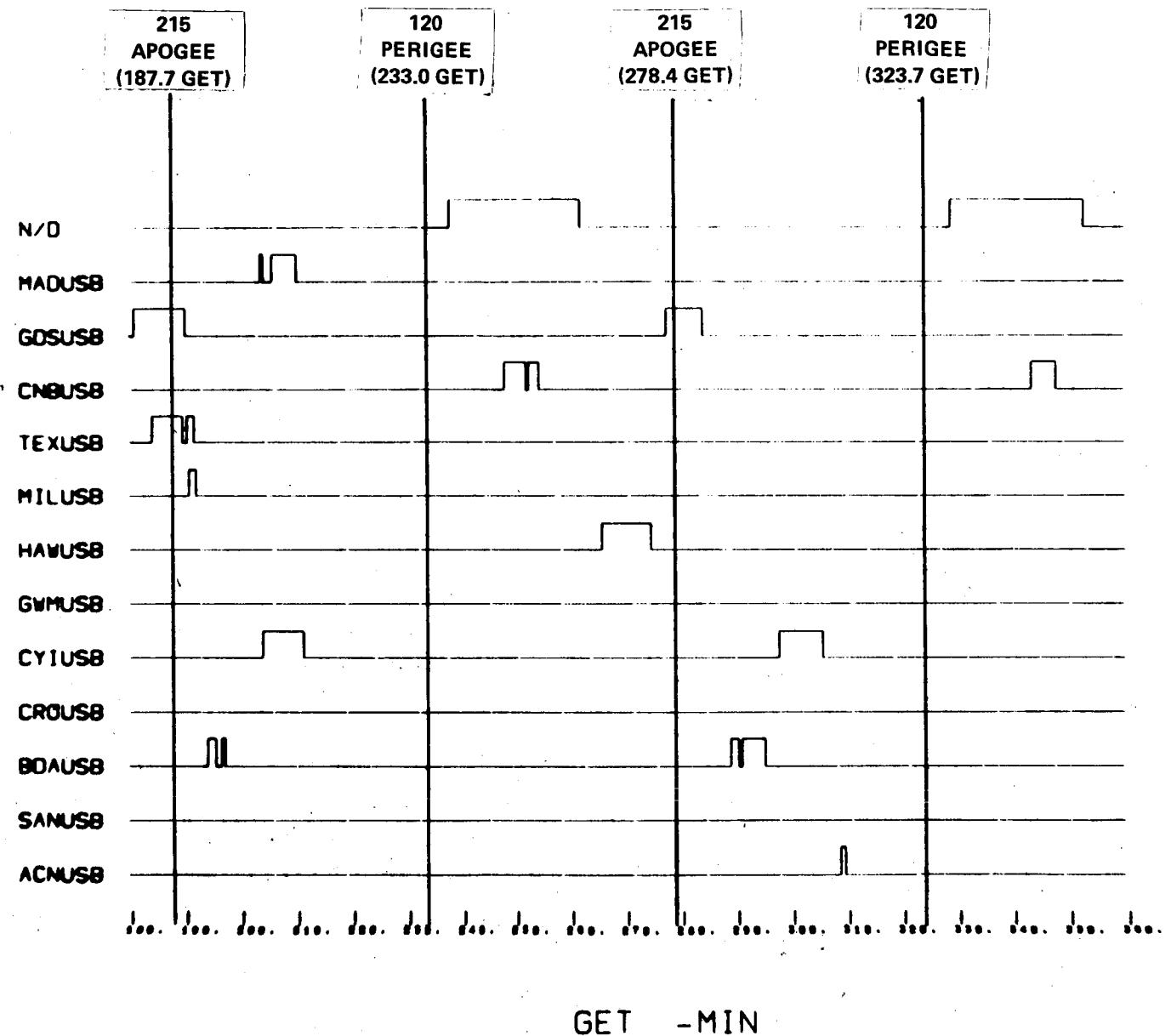
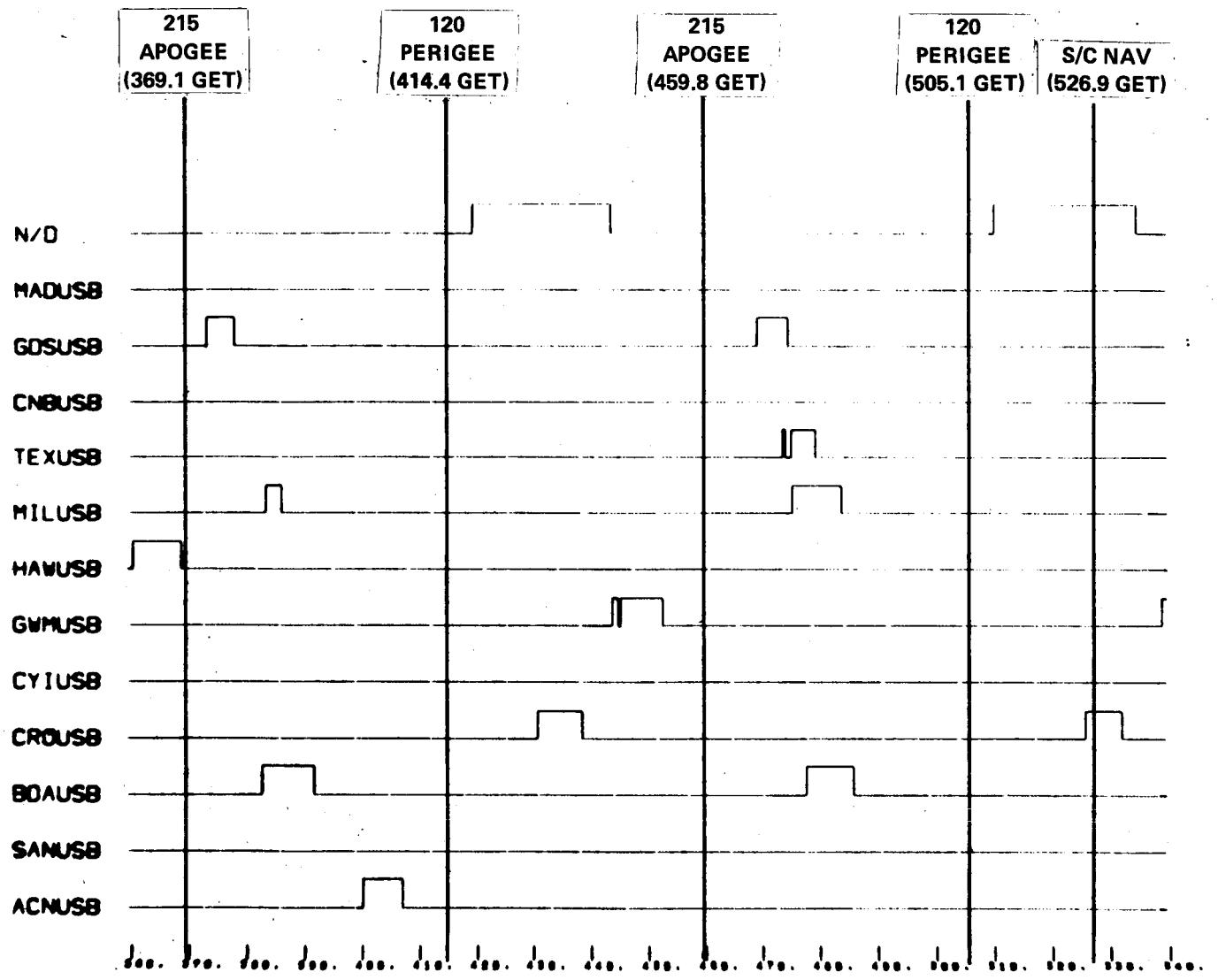


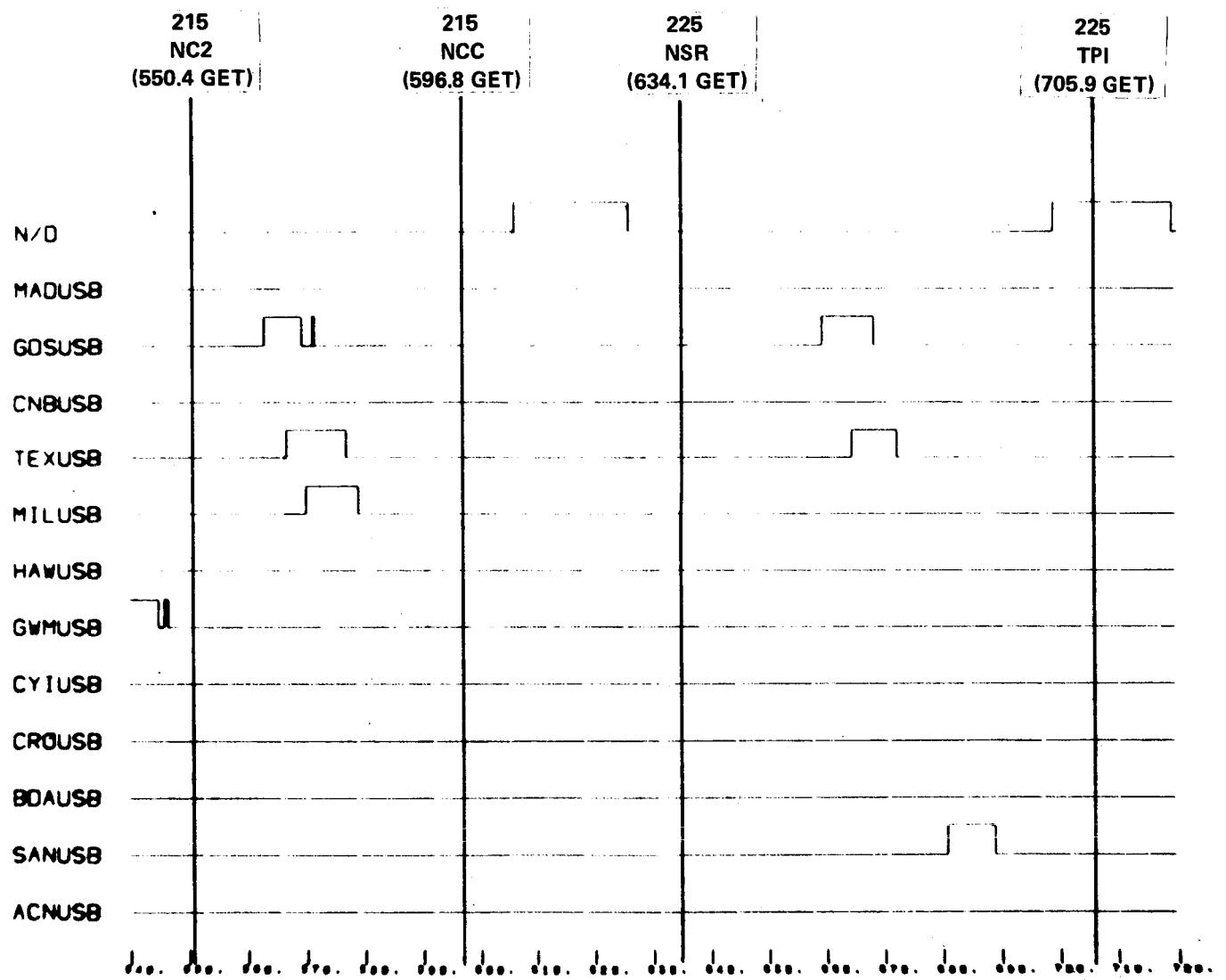
FIGURE 14 - SL-2 M = 8 DAY 7 MINIMUM PHASE OPPORTUNITY



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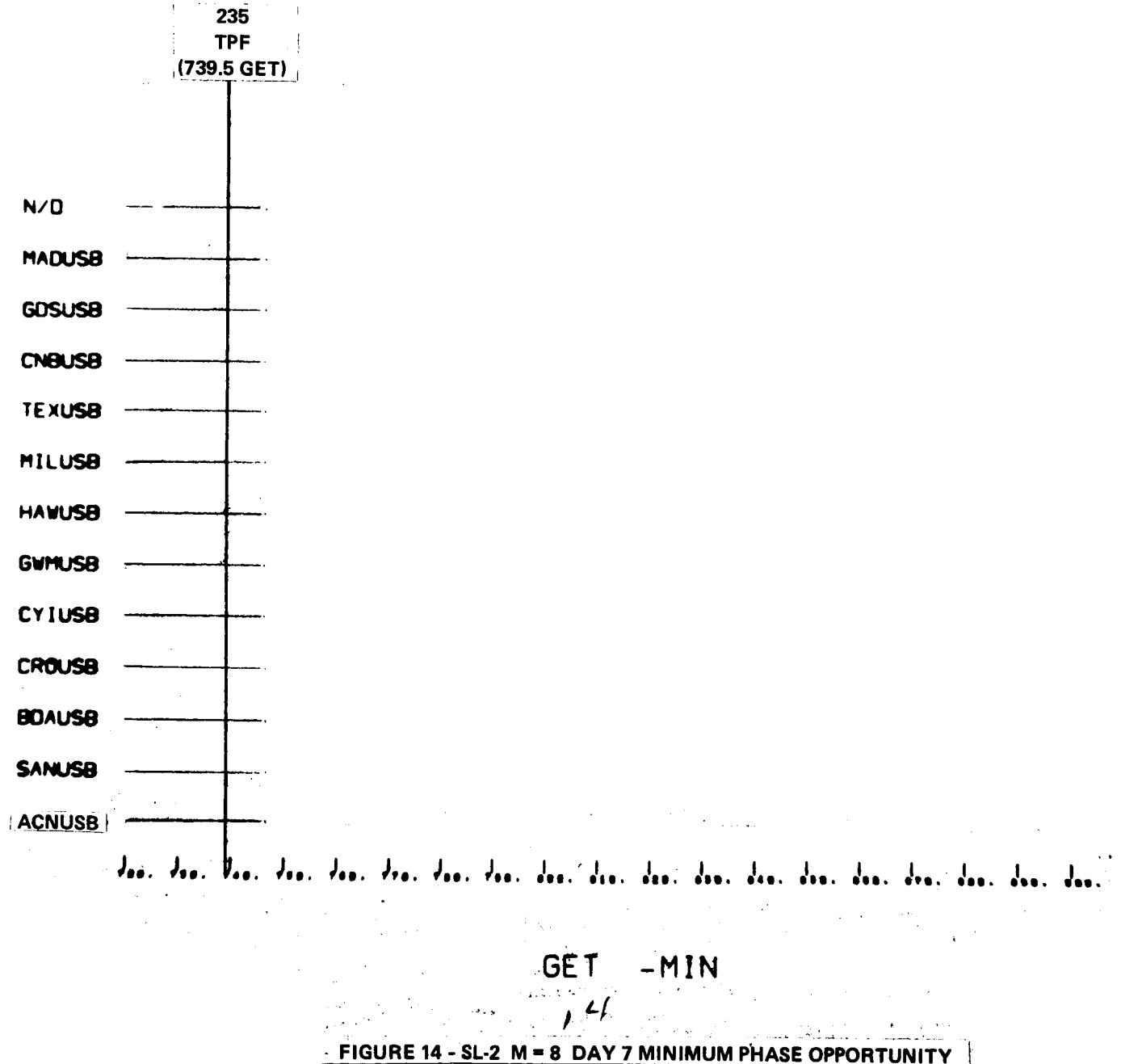
FIGURE 14 - SL-2 M = 8 DAY 7 MINIMUM PHASE OPPORTUNITY

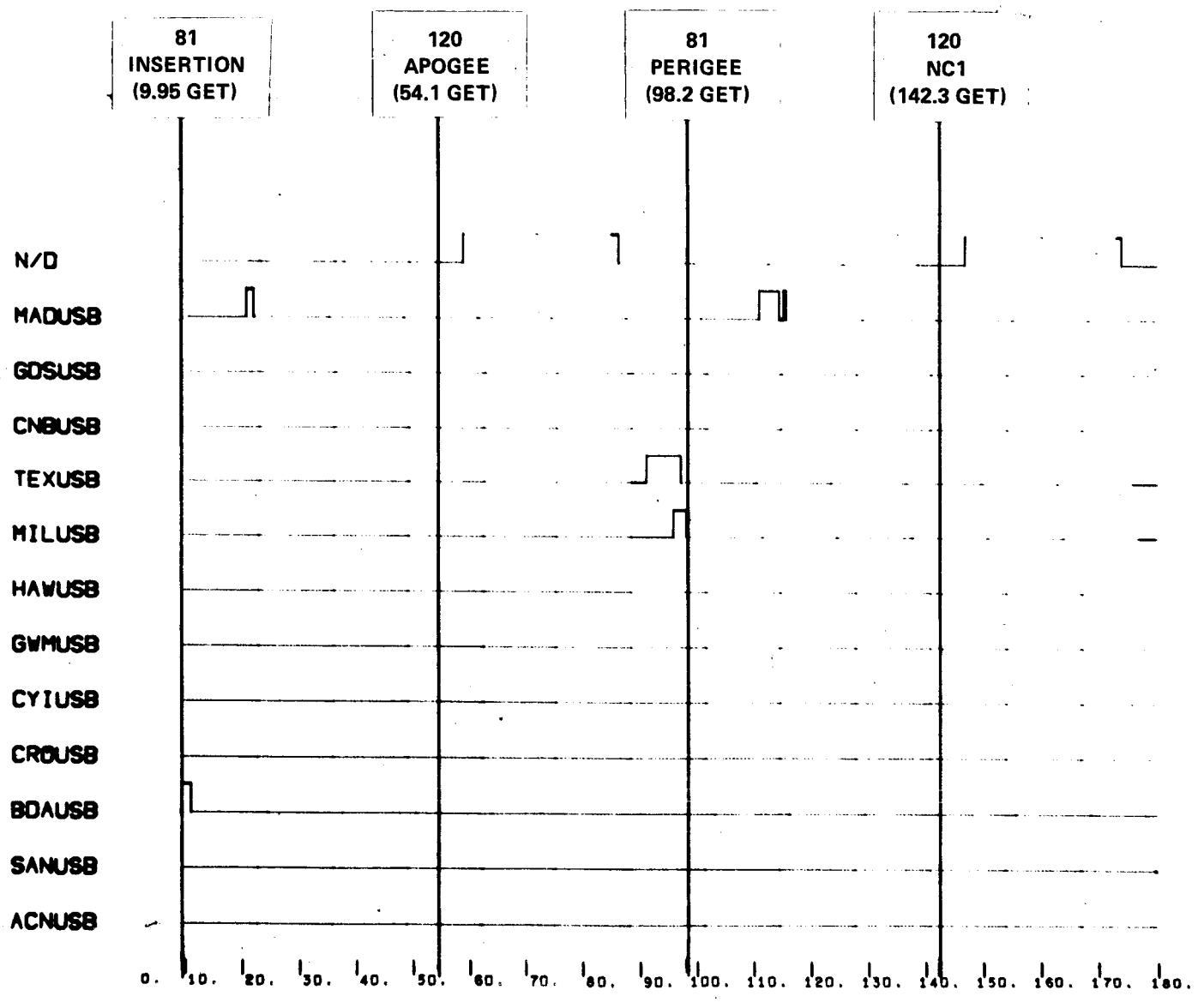


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FIGURE 14 - SL-2 M = 8 DAY 7 MINIMUM PHASE OPPORTUNITY





GET - MIN

FIGURE 15 - SL-2 M = 6 DAY 7 MAXIMUM PHASE OPPORTUNITY

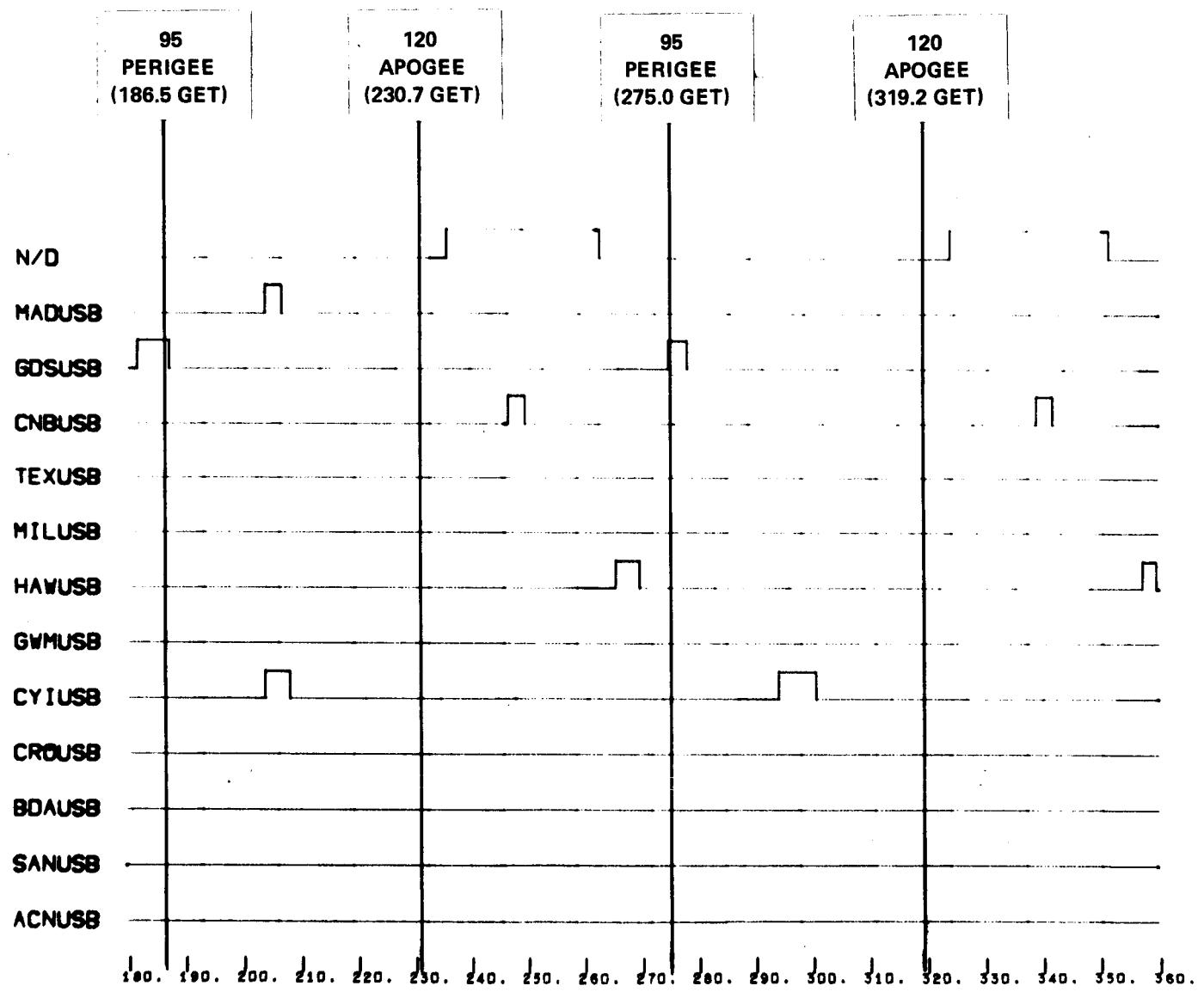


FIGURE 15 - SL-2 M - 6 DAY 7 MAXIMUM PHASE OPPORTUNITY)

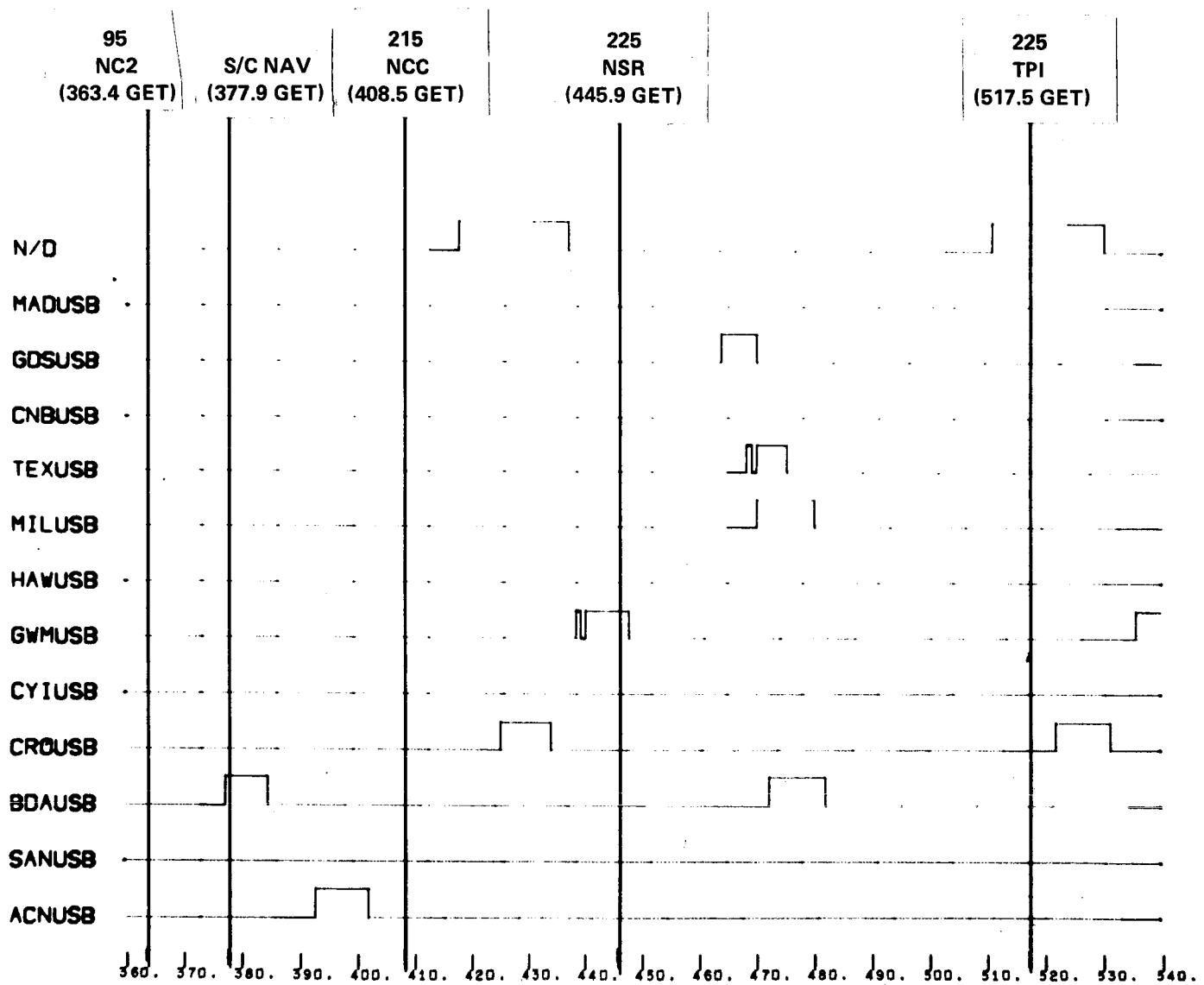


FIGURE 15 - SL-2 M = 6 DAY 7 MAXIMUM PHASE OPPORTUNITY

235
TPF
(551.1 GET)

N/D

MADUSB

GOSUSB

CNBUSB

TEXUSB

MILUSB

HAWUSB

GMUSB

CYIUSB

CRCUSB

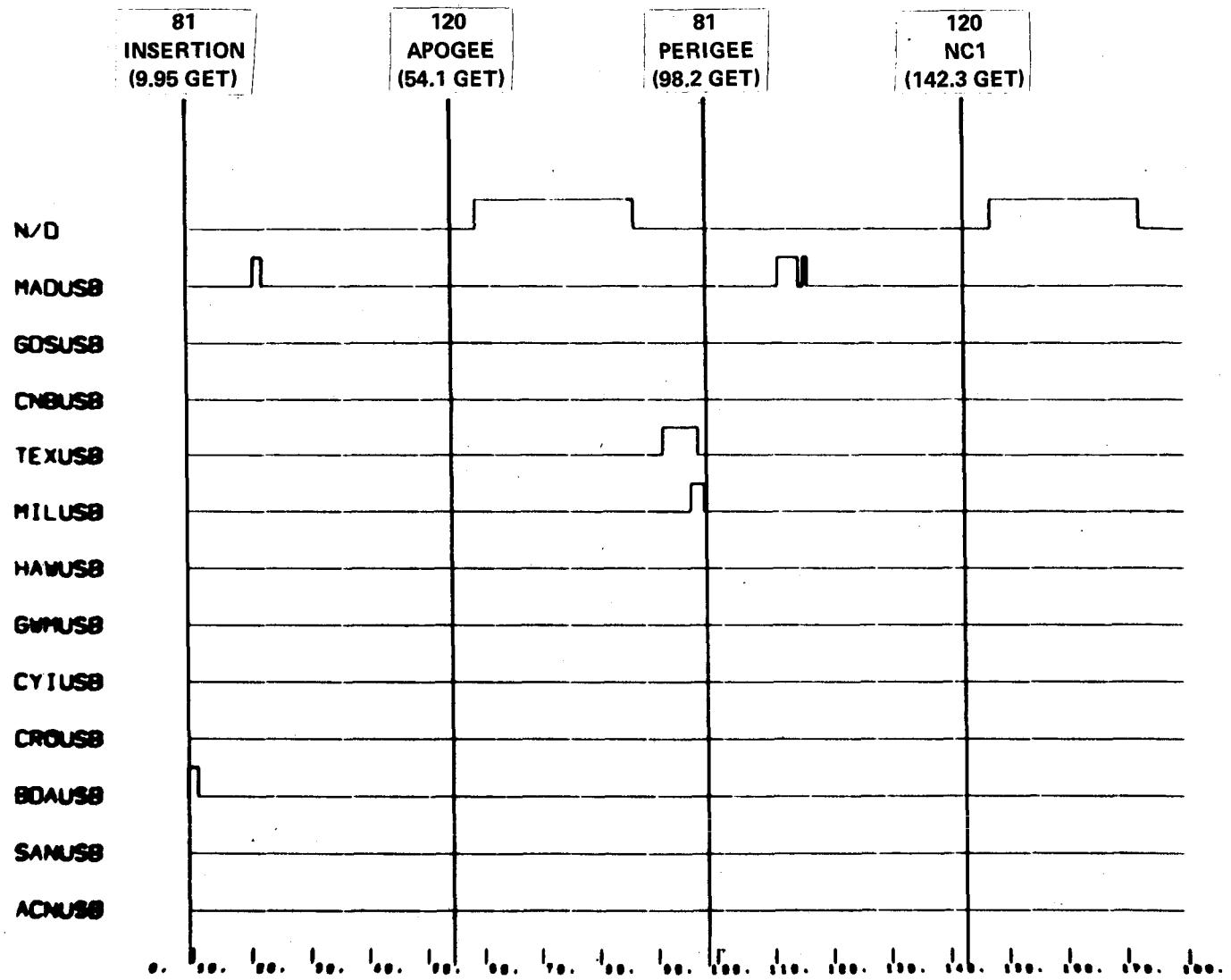
BOAUSB

SANUSB

\$40. \$50. \$60. \$70. \$80. \$90. \$00. \$10. \$20. \$30. \$40. \$50. \$60. \$70. \$80. \$90. \$00. \$10. \$20.

GET - MIN

FIGURE 15 - SL-2 M = 6 DAY 7 MAXIMUM PHASE OPPORTUNITY



GET - MIN

16

FIGURE 16 - SL-2 M = 7 DAY 7 AVERAGE PHASE OPPORTUNITY

0

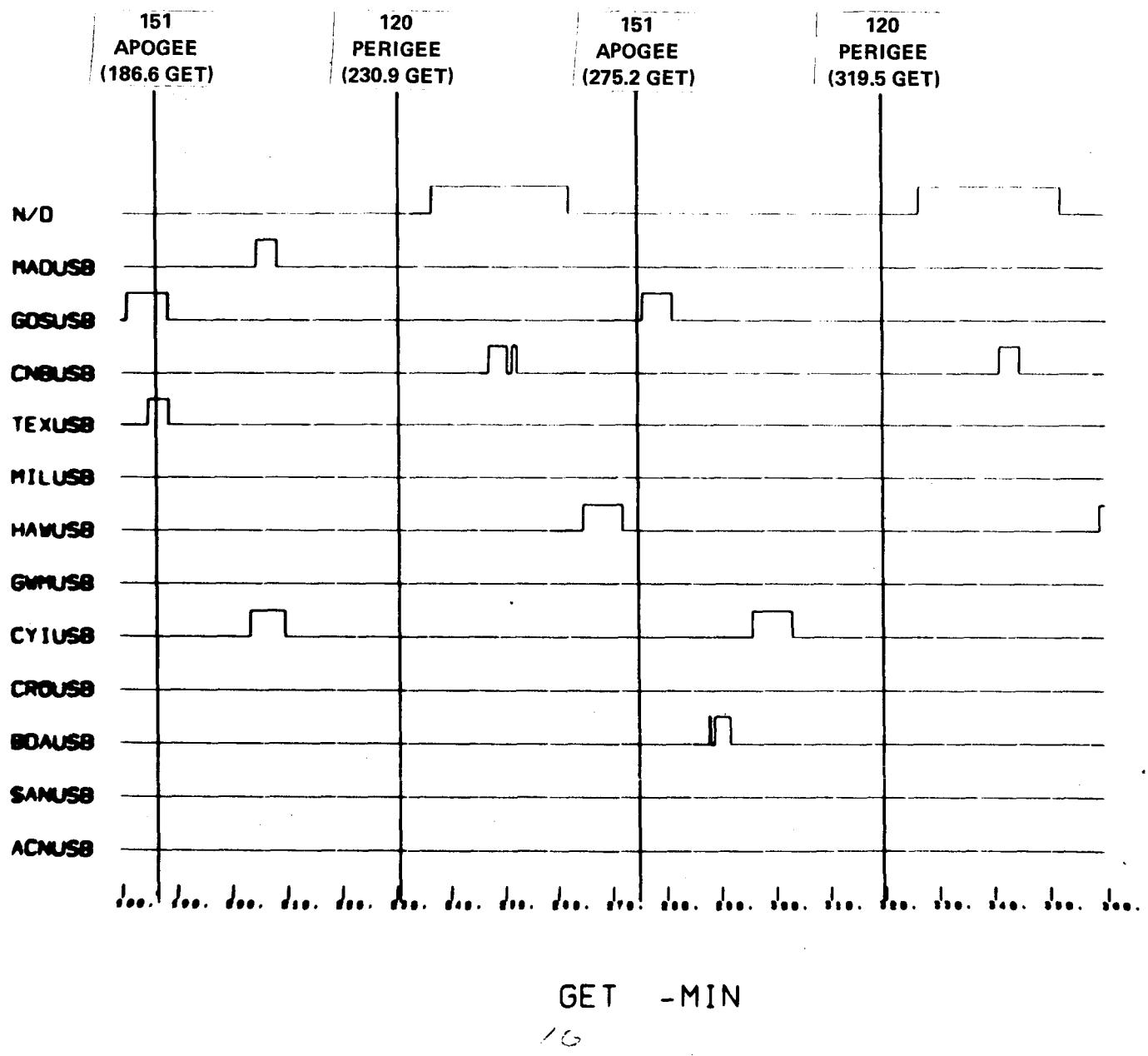
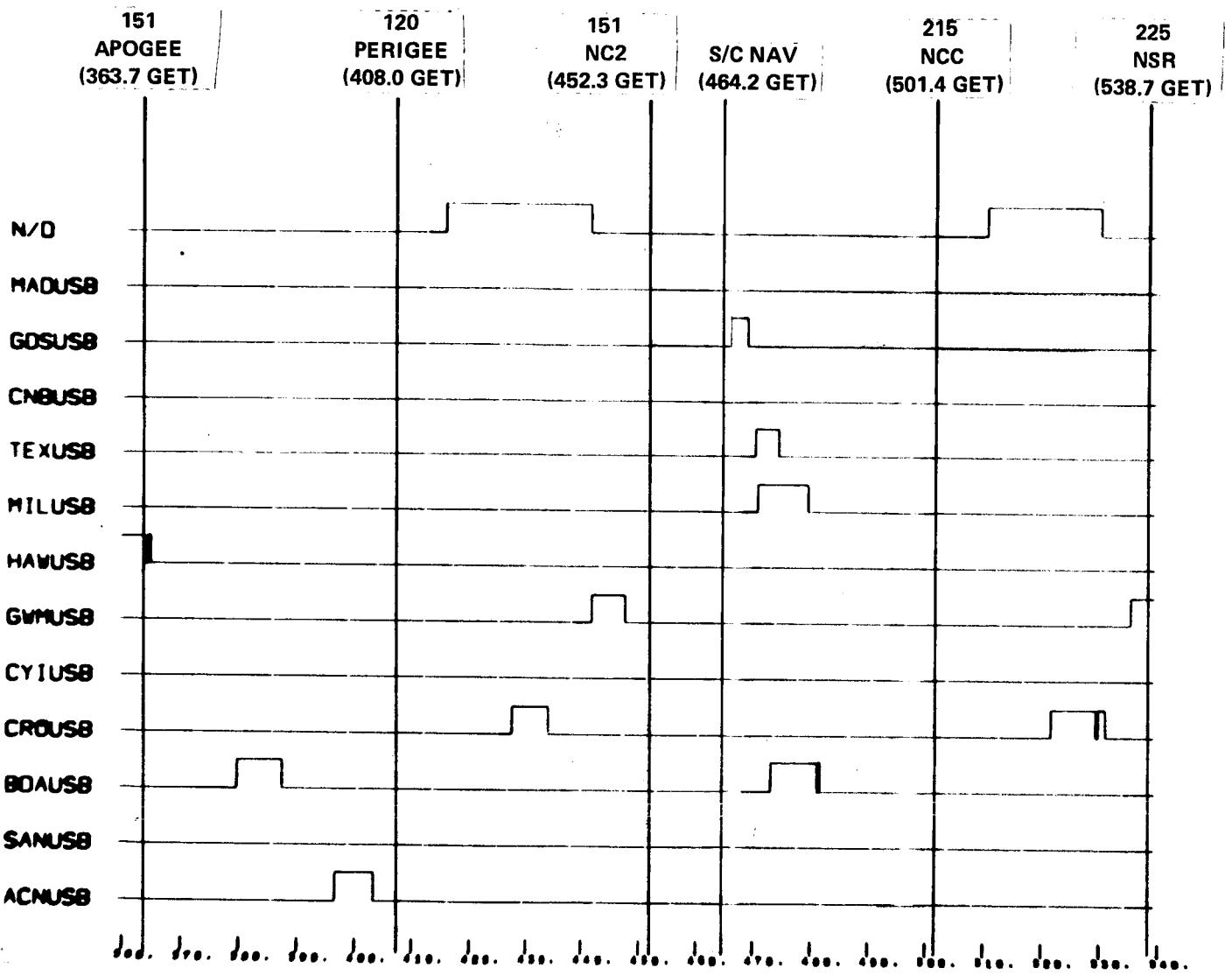


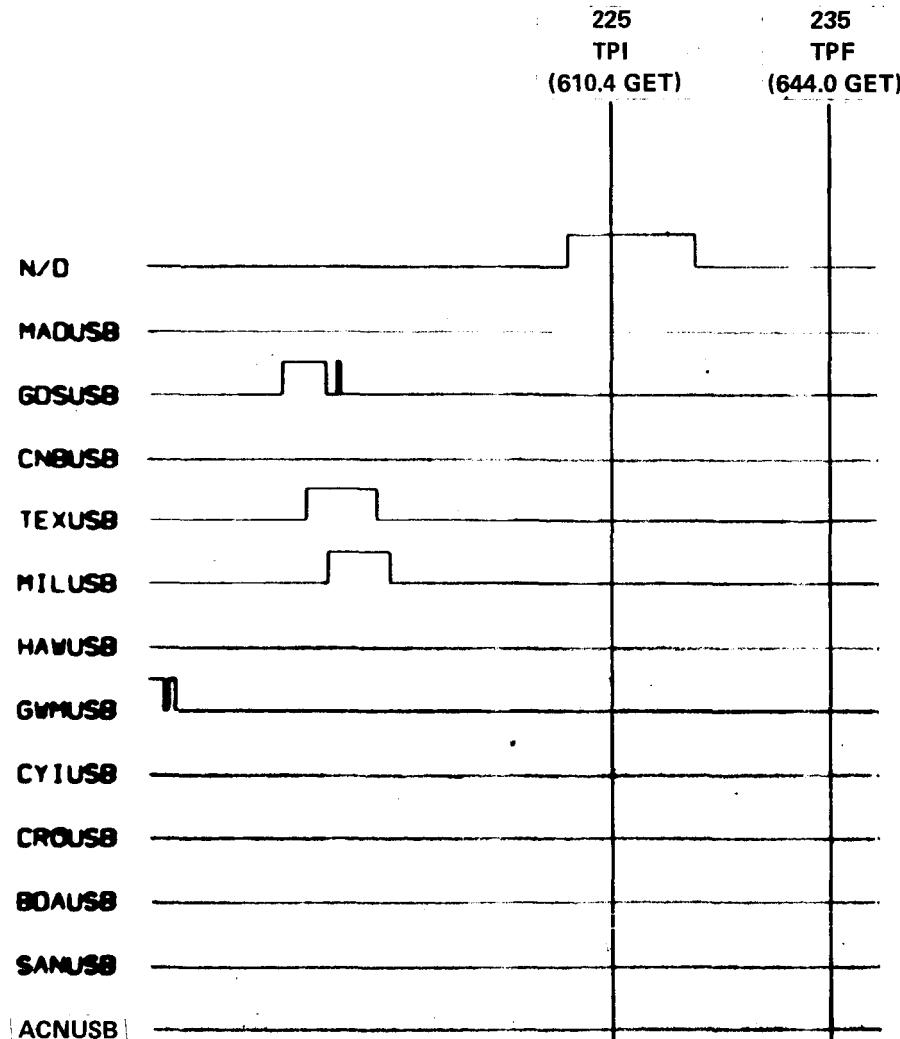
FIGURE 16 - SL-2 M = 7 DAY 7 AVERAGE PHASE OPPORTUNITY



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16

FIGURE 16 - SL-2 M = 7 DAY 7 AVERAGE PHASE OPPORTUNITY



GET - MIN

16

FIGURE 16 - SL-2 M = 7 DAY 7 AVERAGE PHASE OPPORTUNITY

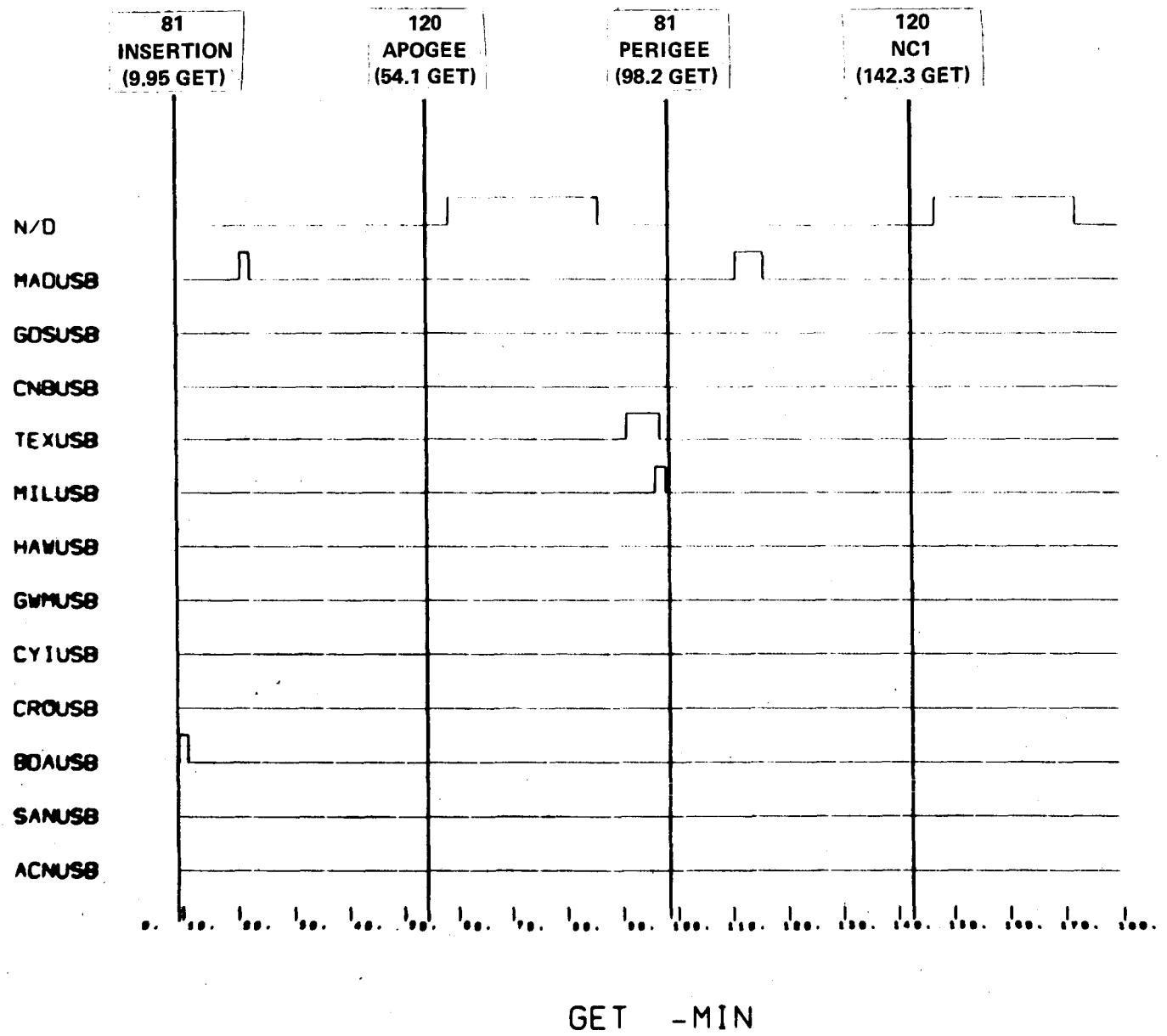


FIGURE 17 - SL-2 M = 8 DAY 7 AVERAGE PHASE OPPORTUNITY

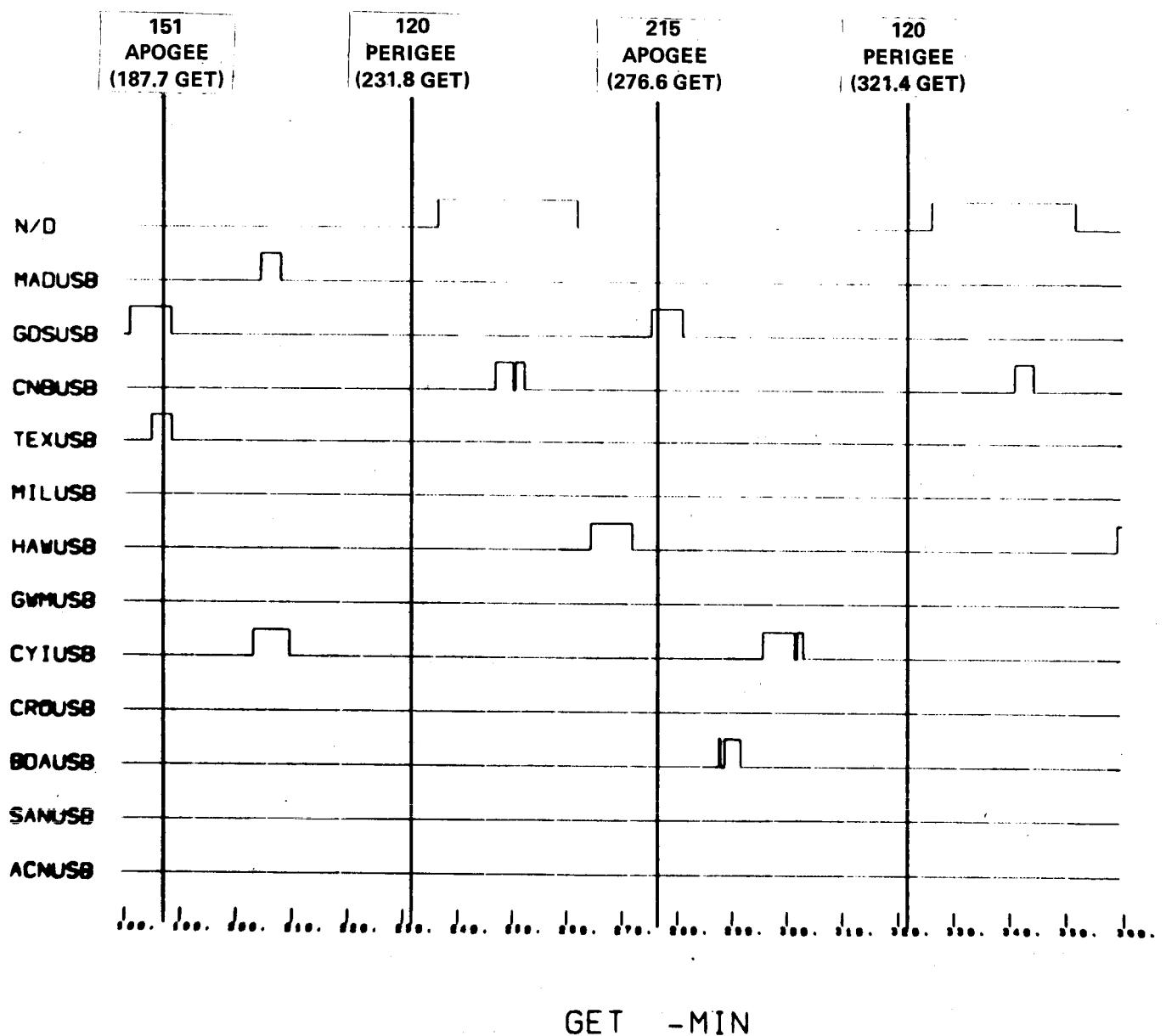
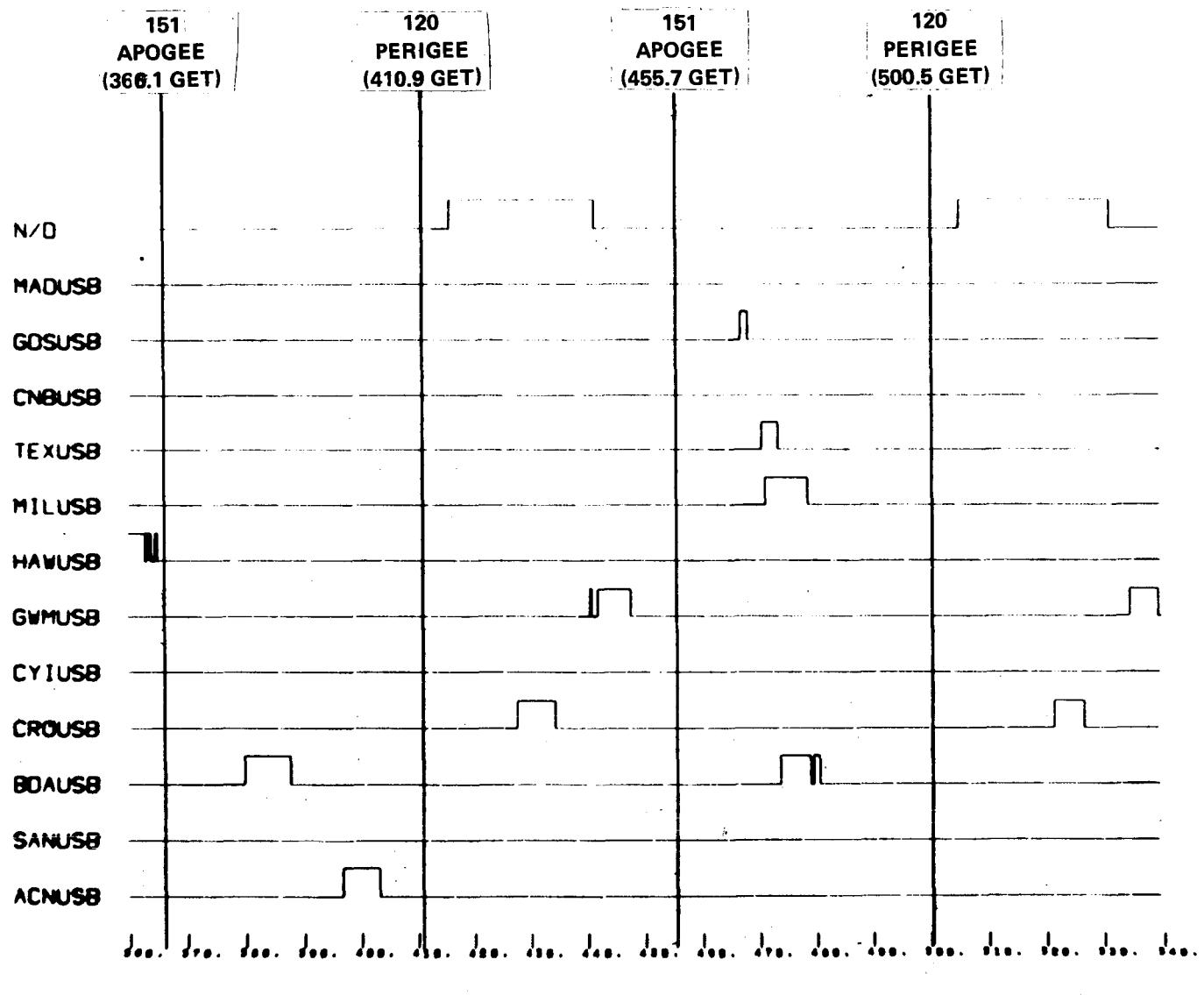


FIGURE 17 - SL-2 M = 8 DAY 7 AVERAGE PHASE OPPORTUNITY



GET - MIN

17

FIGURE 17 - SL-2 M = 8 DAY 7 AVERAGE PHASE OPPORTUNITY

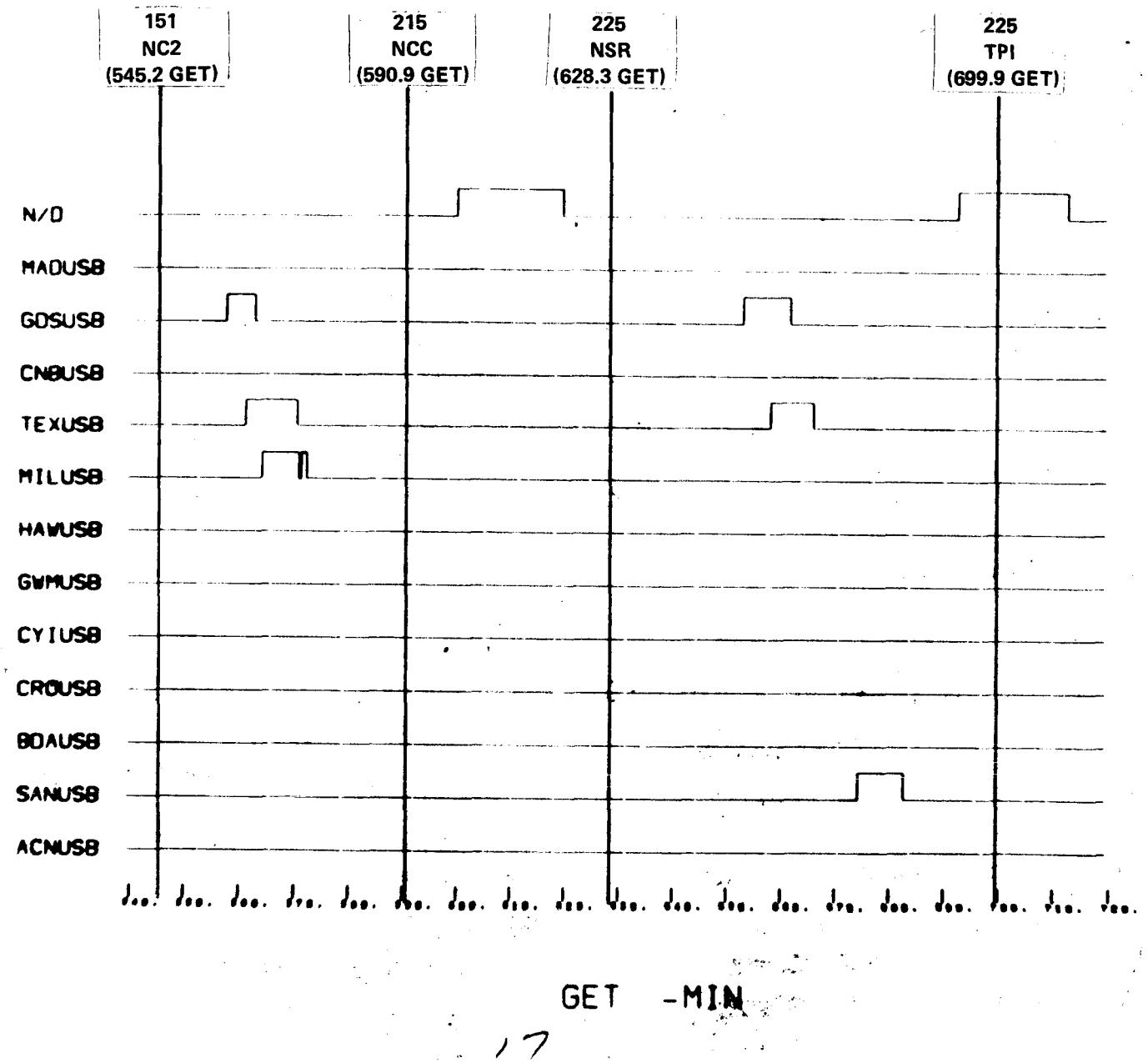
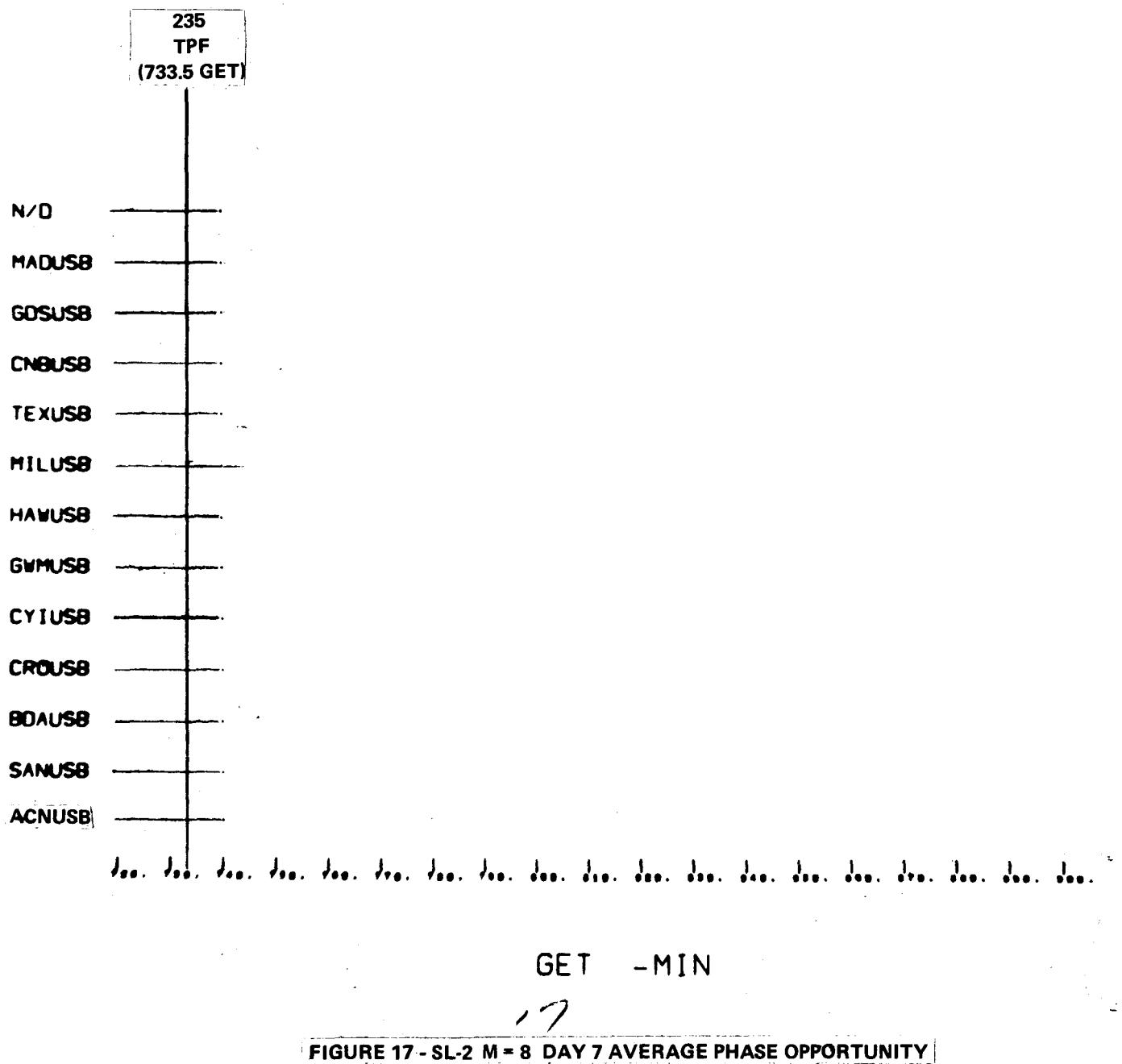
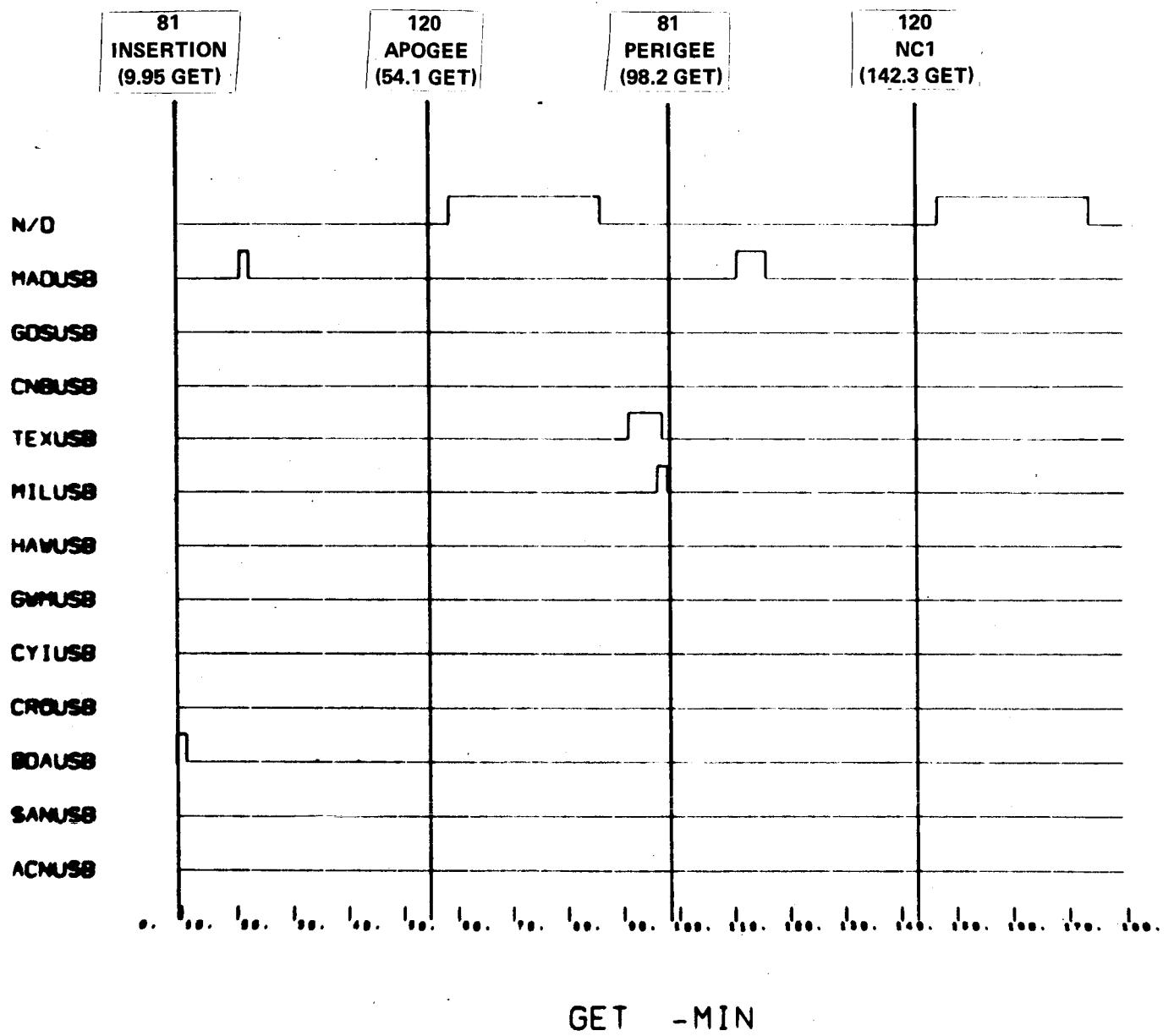


FIGURE 17 - SL-2 M = 8 DAY 7 AVERAGE PHASE OPPORTUNITY





18
FIGURE 18 - SL-2 M = 7 DAY 7 MAXIMUM PHASE OPPORTUNITY

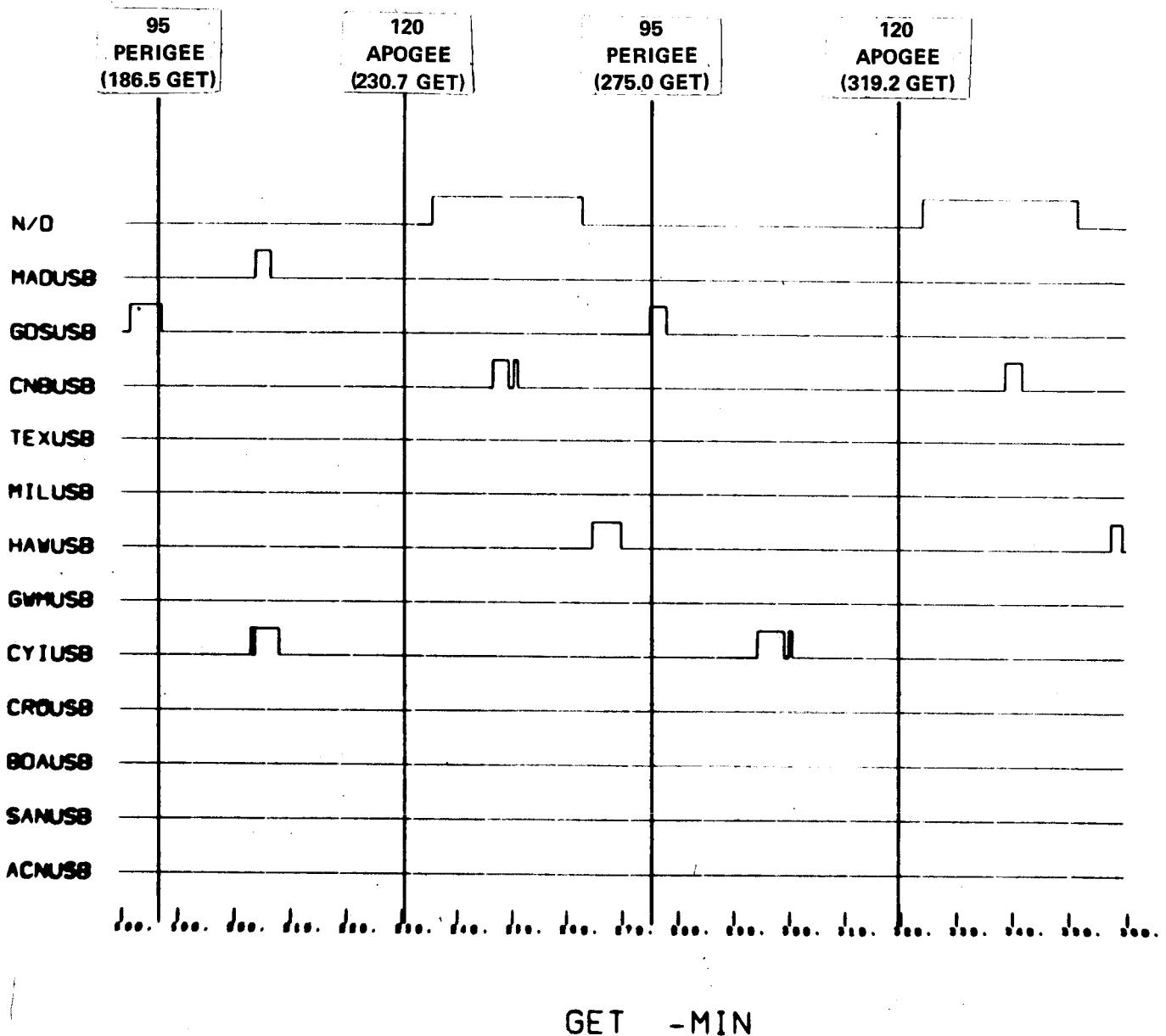
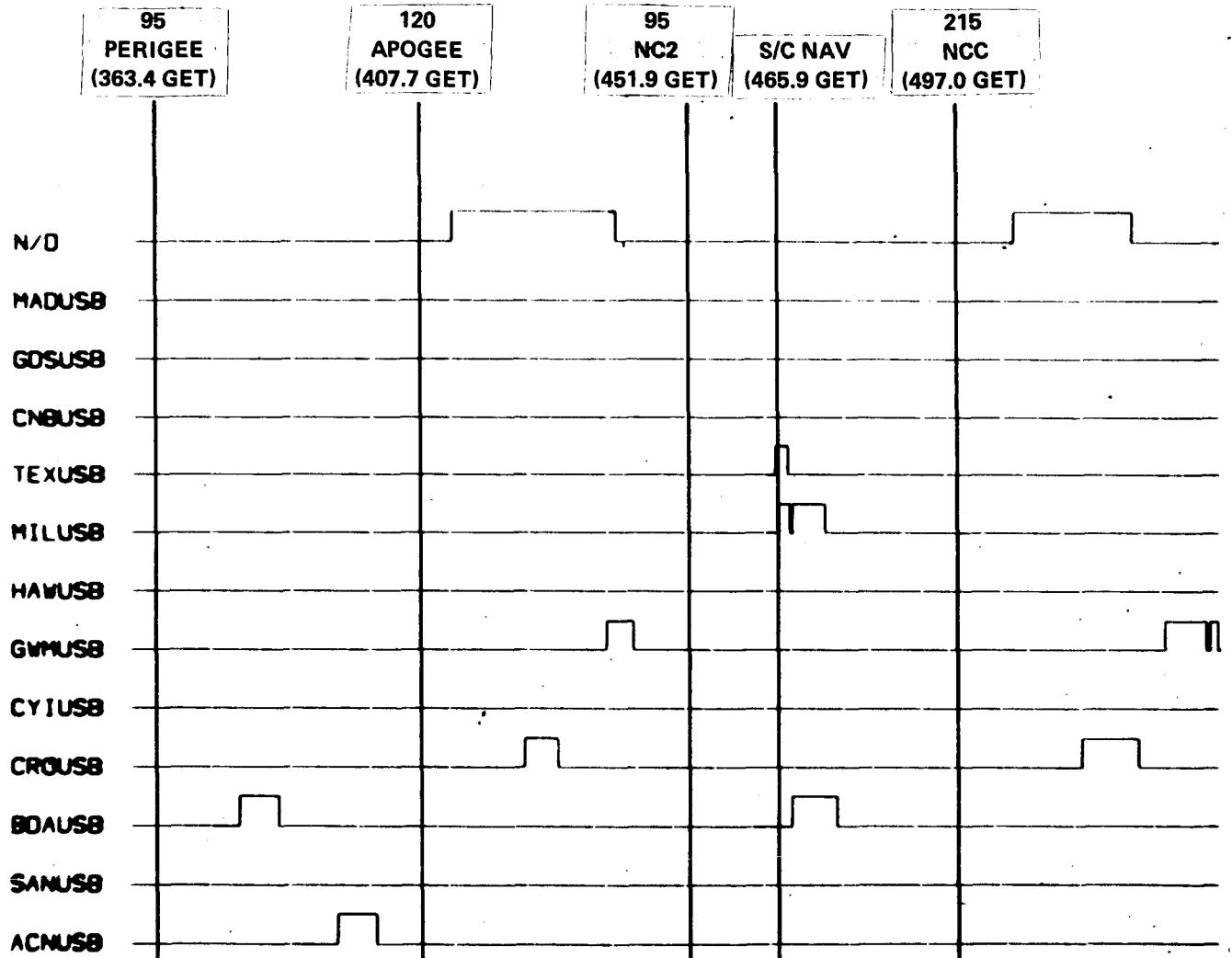


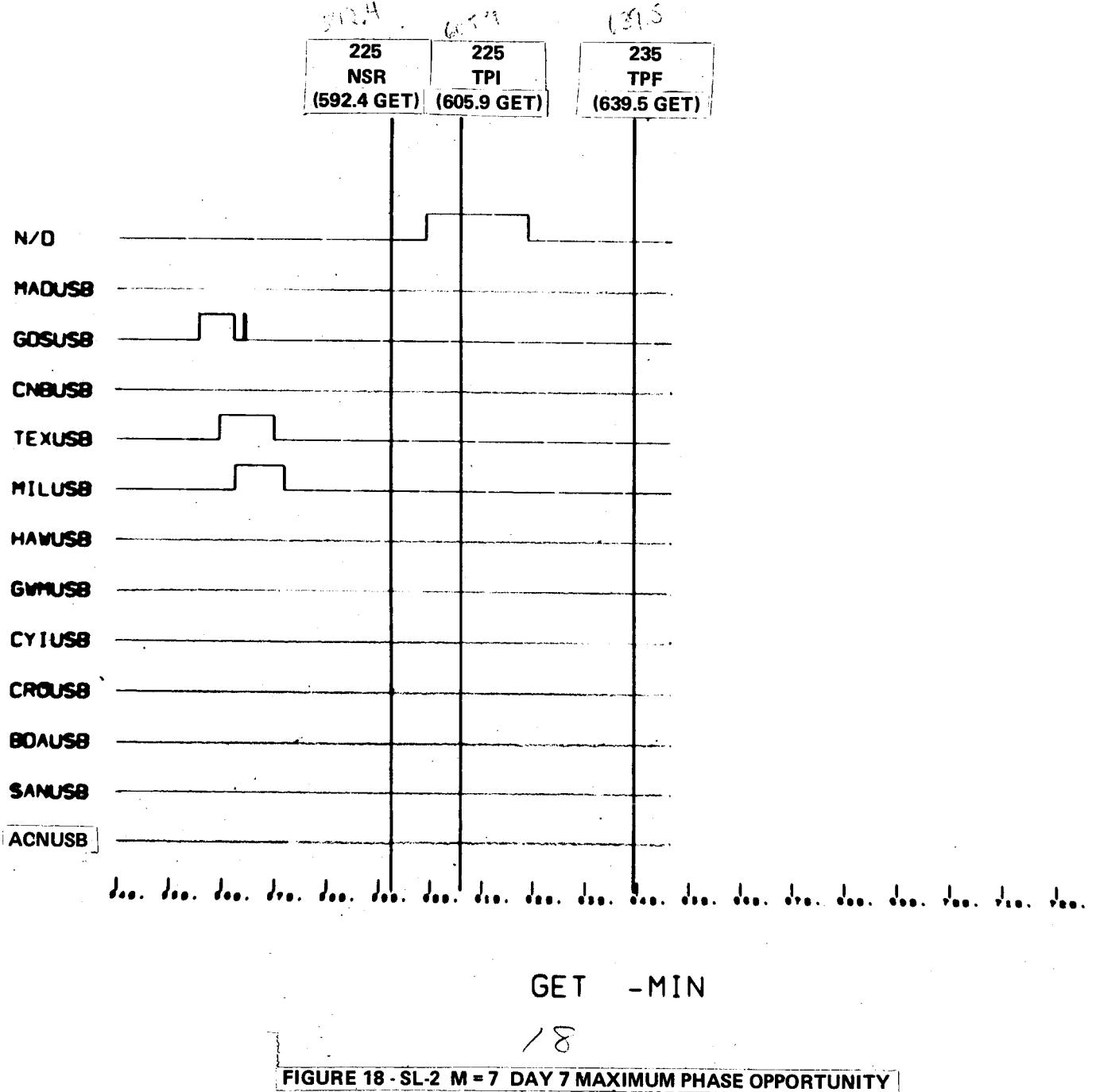
FIGURE 18 - SL-2 M = 7 DAY 7 MAXIMUM PHASE OPPORTUNITY



GET -MIN

18

FIGURE 18 - SL-2 M = 7 DAY 7 MAXIMUM PHASE OPPORTUNITY



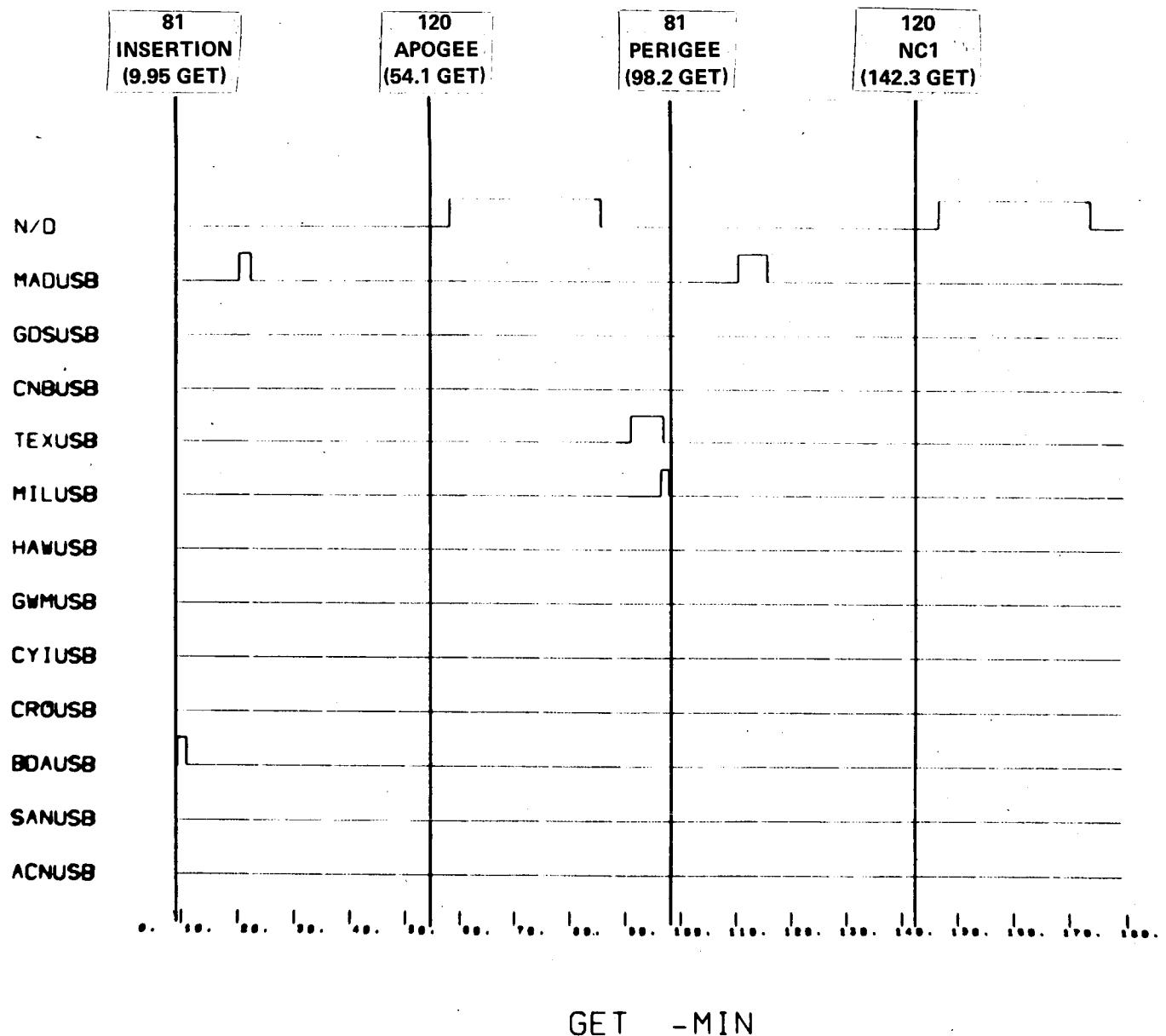
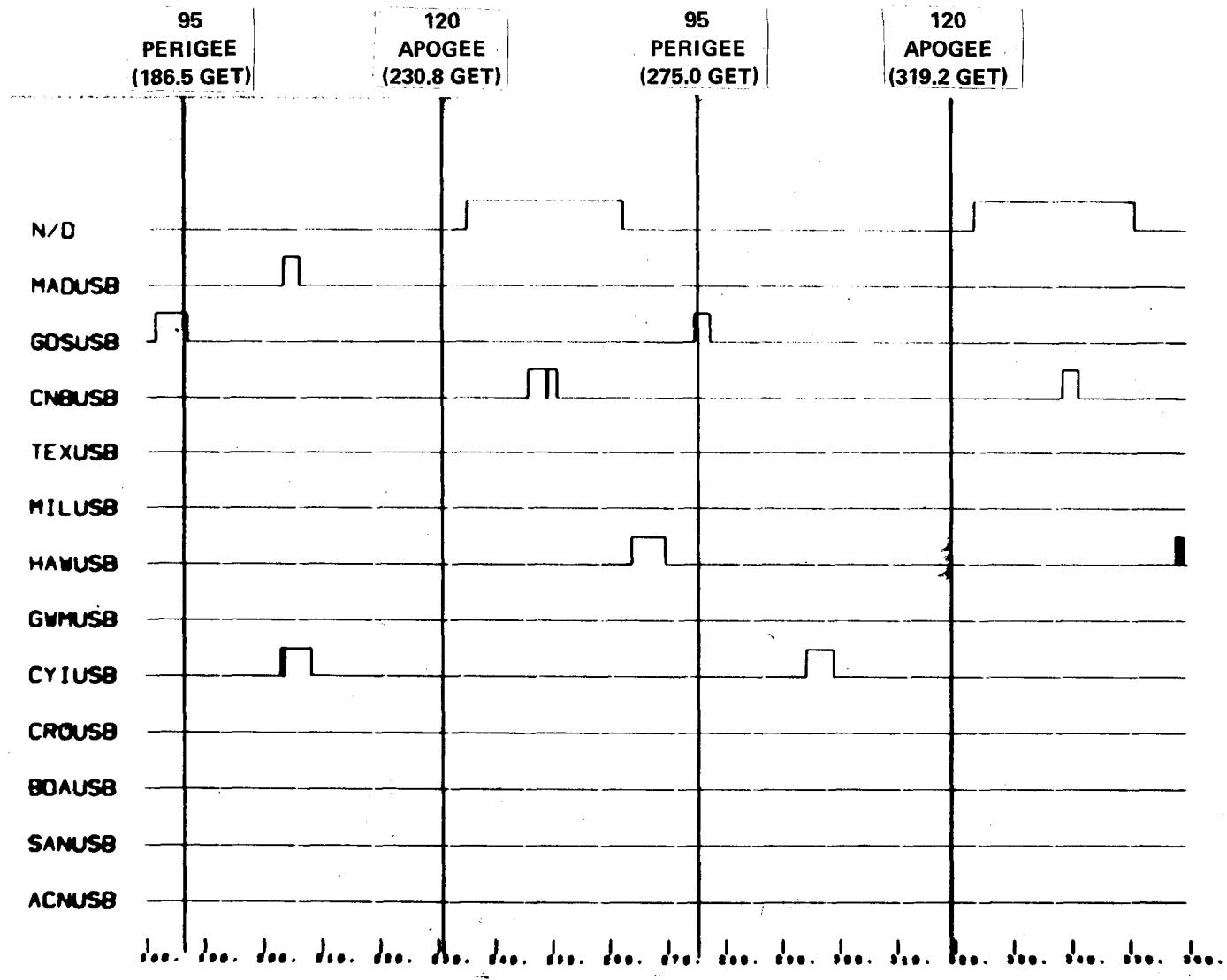


FIGURE 19 - SL-2 M = 8 DAY 7 MAXIMUM PHASE OPPORTUNITY



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19
FIGURE 19 - SL-2 M = 8 DAY 7 MAXIMUM PHASE OPPORTUNITY

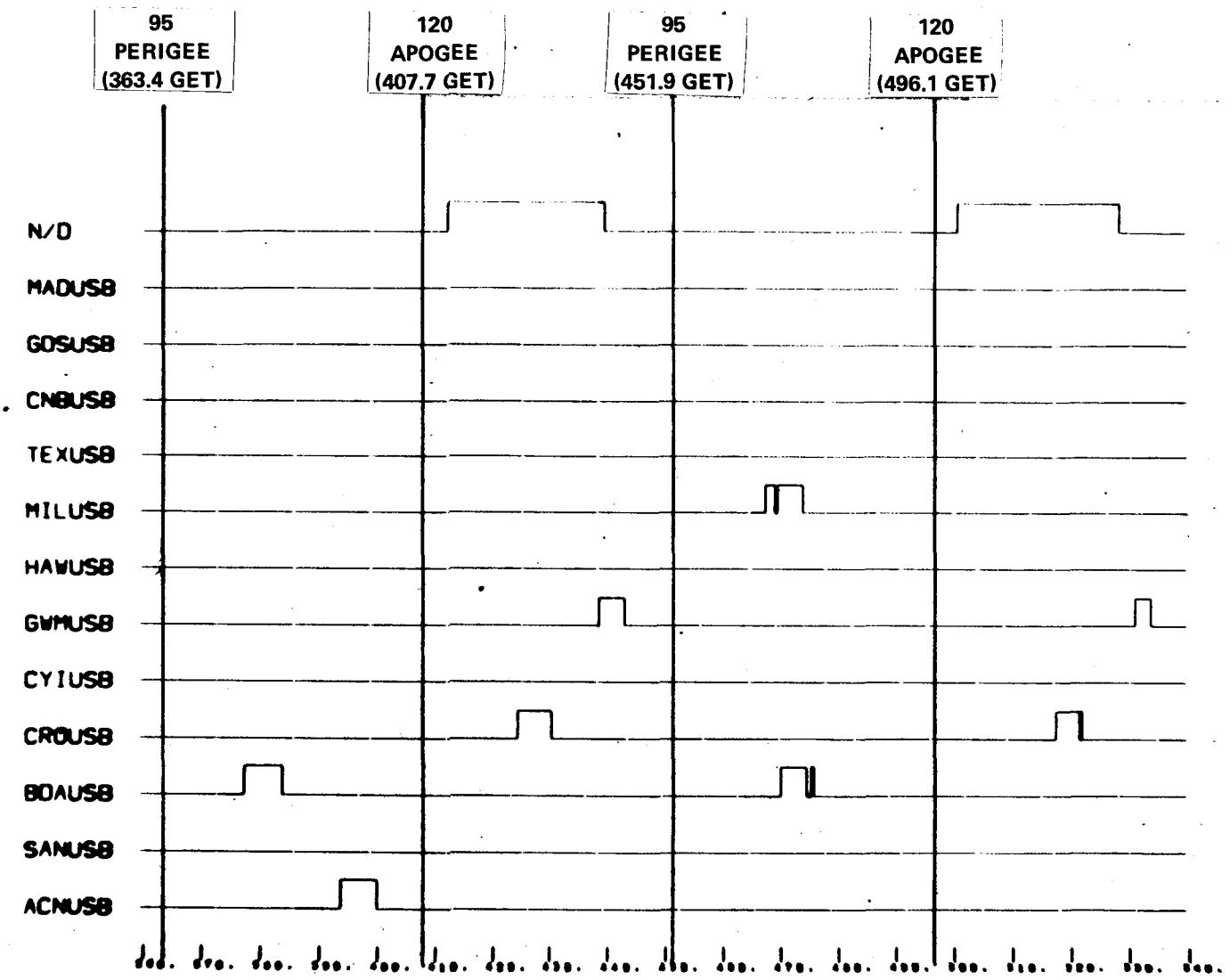


FIGURE 19 - SL-2 M = 8 DAY 7 MAXIMUM PHASE OPPORTUNITY

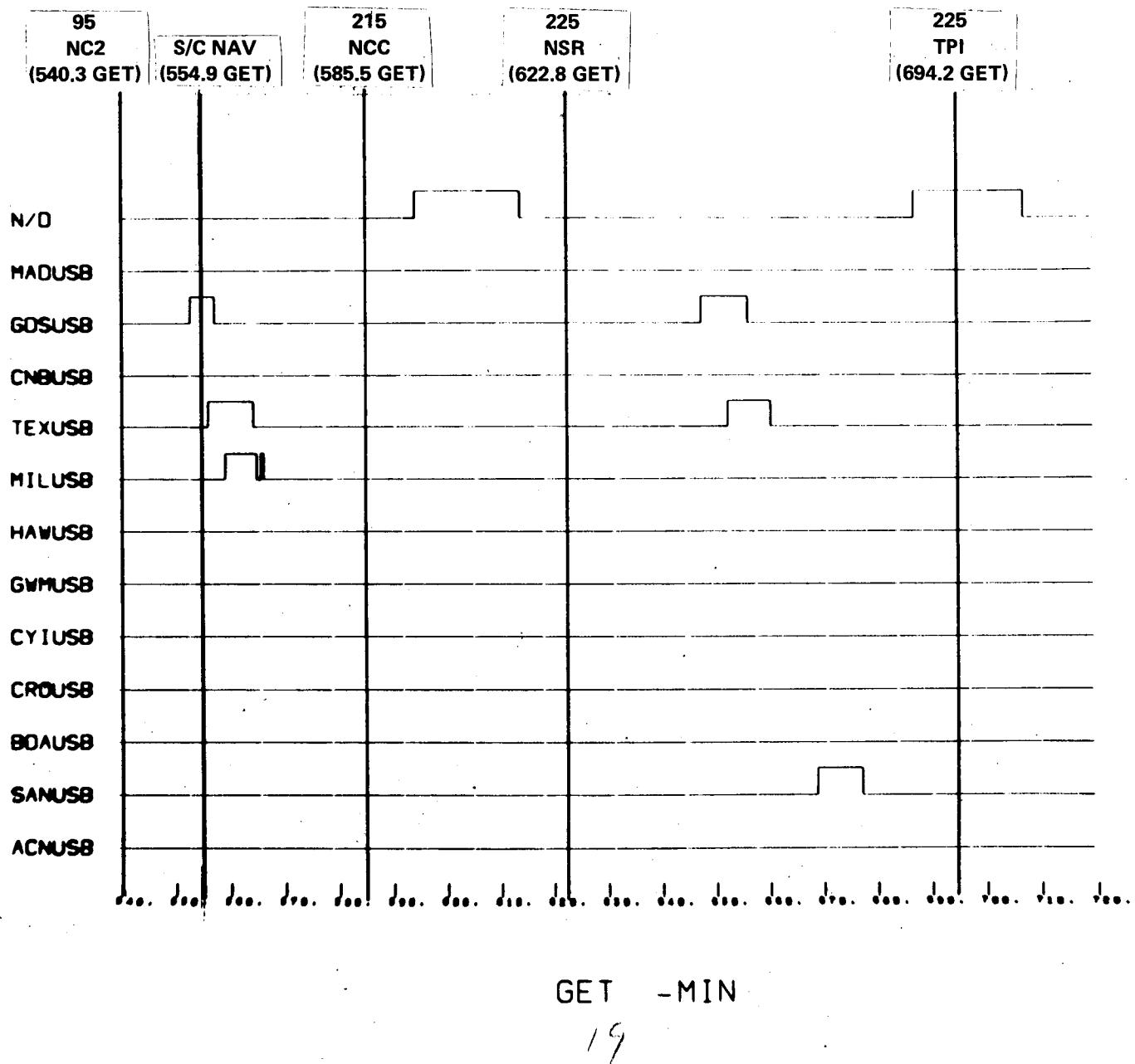


FIGURE 19 - SL-2 M = 8 DAY 7 MAXIMUM PHASE OPPORTUNITY

235
TPF
(727.8 GET)

N/D

MADUSB

GOSUSB

CNBUSB

TEXUSB

MILUSB

HAWUSB

GWMUSB

CYIUSB

CROUSB

BOAUSB

SAMUSB

ACNUSB

do. do.

GET - MIN

19

FIGURE 19 - SL-2 M = 8 DAY 7 MAXIMUM PHASE OPPORTUNITY